Elizabeth City State University
Office of Naval Research

1997
Final Report
Instrumentation for Educational Use

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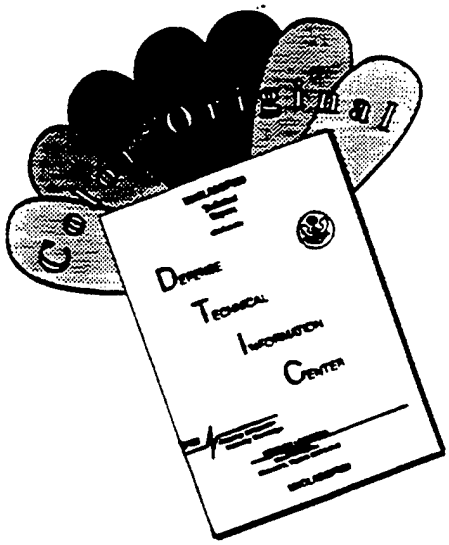
DISCLAIMER NOTICE



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Final Report
Instrumentation for Education
Table of Contents

Section I

- Description
- Current ONR-NERT Program Description
- Curriculum Impact
- Final Report on Contracted Services
  - Watson Electrical Construction Co.
  - Swimme & Son General Contractors
  - ADNET Systems, Inc.

"ECSU Instrumentation for Educational Use"
Final Report

Description

The goal of the ECSU Instrumentation for Educational Use program was to provide Silicon Graphics Workstations and a high resolution data display panel to be used in the instruction of the courses in computer graphics, system programming and in support of the research by undergraduate research teams funded in the Nurturing ECSU Research Talent Program. Renovation of rooms in Lester Hall were required to prepare it to house the SGI workstations. The workstations were integrated into the existing network using ATM technology.

The typical class size at ECSU in computer science is 25 students. The System Programming and Computer Graphics courses were redesigned to make heavy use of the Workstations. In addition, a new course in computer visualization was introduced which also required use of the workstations. These courses could only be implemented if the number of available workstations is sufficient to avoid contention with the student researchers and research faculty.

Purchase of a projection panel was required to support the educational use of the SGI Workstations. The projection panel allowed for viewing of the high-quality image generated by the advanced SGI graphics workstations. Use of the projection panel greatly enhanced discussions and lectures in all classes using the SGI workstations.

Twenty three SGI Workstations are housed in Lester Hall rooms 113- 115. The Mathematics and Computer Science Department also renovated 116 Lester Hall for this project. Room 116 is a lecture room with an initial seating capacity of 200. Initially however, 35% of the seats with desk were unusable. Renovation plans involved partitioning the room and removing the last 5 rows of seats. The remaining seats in 116 LH have been replaced with new ones. The cost of removing the 5 rows of seats and replacing the remaining seats was paid by Elizabeth City State University. The cost of electrical upgrades, purchase of workstations and ATM networking were paid by grant funds.

Current ONR-NERT Program Description

The Nurturing ECSU Research Talent Grant (NERT) focuses on undergraduate education and undergraduate research experiences in computer science. Nurturing these young researchers is our primary concern. Highest priority is given to providing them with the guidance and skills to insure their entrance and success in graduate school. Further, each student in our program learns

the fundamentals of scientific research as they conduct investigations in parallel processing and computer graphics. Student development activities include the following:

a) Recruitment of 20 high ability minority students
b) Providing a summer program for recruited students;
c) Providing undergraduate research experiences;
d) Providing a mentor, graduate school counseling and GRE preparation;
e) Providing financial support for students in the form of research assistantships; and
f) Providing funds for student travel.

A second important component of NERT addresses infrastructure of the Mathematics and Computer Science Department of ECSU. Funded activities include the following:

a) Enhancement of current computer graphics and system programming courses;
b) Development of a new course in computer visualization;
c) Acquisition of computer equipment appropriate to support undergraduate research;
d) Establishing a visiting lecture series in computer science;
e) Hiring a UNIX network manager.

Curriculum Impact

As a result of the NERT grant, the Instrumentation for Educational Use grant and the efforts of department faculty (especially Drs. Houston and Hayden) students in the Mathematics and Computer Science Department of ECSU now take a revised System Programming Course; a revised Computer Graphics Course; and a new Computer Visualization Course. The old computer graphics course was primarily a theory course given that the hardware was not in place to support a more hands-on course. The new course is laboratory based using Renderman Software and the Silicon Graphics workstations. The University catalogue descriptions for these courses (both old descriptions and new descriptions) are listed below.

CSC 320: System Programming(OLD): Logical structure of computer software, operating systems, compilers one and two pass assemblers, linkers, loaders and macroprocessors, macro calls and macro expansion.

CSC 320: System Programming(NEW): UNIX Shell programming, file manipulation, I/O redirection, pipes, control structures, and C-Shell scripts. UNIX utility programs and programming tools including AWK.

CSC 415 Computer Graphics (OLD): Theory underlying various graphic operations; writing and producing two or three dimensional graphics software.

CSC 415 Computer Graphics (NEW) An overview of the principles and methodology of interactive Computer Graphics. Characteristics of display devices (e.g. refresh buffer, raster scan); representing primitive objects (lines, curves, surfaces) mathematical manipulation of graphical objects; two-and-three dimensional transformations (translations, scaling, rotation); hidden lines and surfaces, shading and coloring, clipping algorithm, animation techniques.

CSC 250: Introduction to Computational Science and Computer Visualization Techniques. Basic computer concepts, hardware, software, operating systems commands, database analysis and on-line accessing of applications of computational methods to scientific disciplines, computer graphics, multimedia displays and other visualization techniques.

Two undergraduate research teams have been organized as a result of this grant. ATM Networks and Computer Visualization Teams are active with faculty mentors. Undergraduate research teams are the heart of the ONR-Nurturing ECSU Research Talent program. Both team reports for the 1996-97 academic year are included in the appendix to this document.

FINAL REPORT
CONTRACTED SERVICES

A. WATSON ELECTRICAL CONTRACTORS (ELECTRICAL UPGRADES)

B. SWIMME & SON GENERAL CONTRACTOR (BUILDING MODIFICATIONS)

C. ADNET INC. (NETWORKING UPGRADE TO ATM)

JOB: UPDATE ELECTRICAL AND SECURITY SYSTEM OF LESTER HALL

CONTRACTOR: WATSON ELECTRICAL CONSTRUCTION CO.

SCOPE OF WORK: Furnish labor and material for installation of electrical work to include:

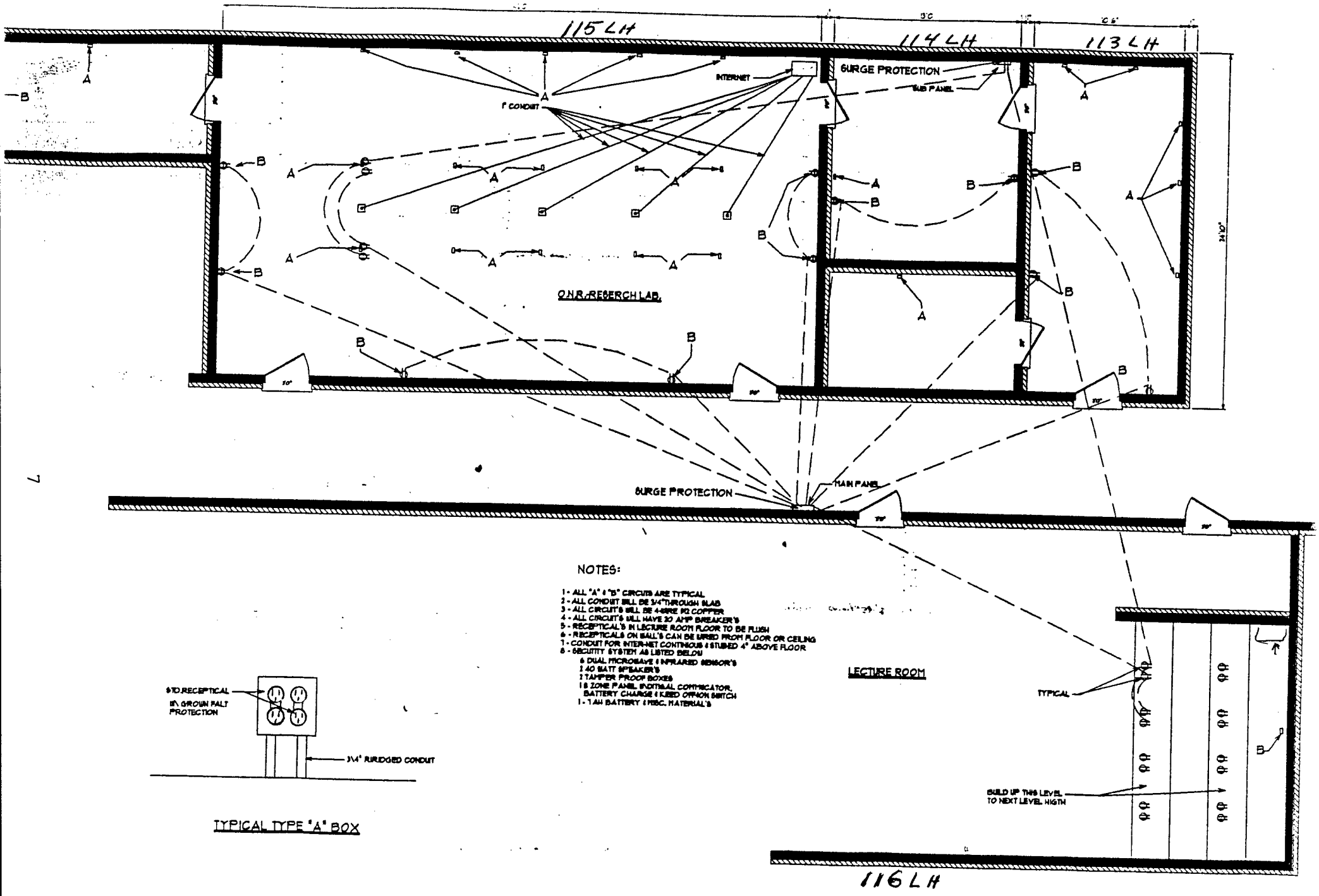
- Build up steps in lecture hall, add 8 double duplex receptacles in floor and recarpet.
- Run 5 1" conduits below floor and stub up at internet and at each designated location in ONR Research Lab.
- Install security system per drawing
- Five type A boxes on exterior wall were deleted.
- All work was completed as per drawing received on July 18, 1995
- Modify panel in ONR lab to isolated ground, which required installation of an isolated ground bar and a grounded bar in panel. Add new breakers in panel to feed new power poles in research lab.
- Run ground wire from main electric room to panel in research lab and in telephone room for fiber optic cable. Make all necessary ground connections in telephone room and to cold water pipe in electric room. Two separate grounds were isolated from electric room.
- Install surge and lighting arresters on panel in research lab and on panel in room 113. Arresters were cutler hammer - CHSA 1240. Make all necessary connections for surge and lighting arresters.

JOB: BUILDING UPGRADES TO LESTER HALL

CONTRACTOR: SWIMME & SON

SCOPE OF WORK:

- Furnish new blackboard 48x72 in room 114 LH
- Install four double duplex receptacles on back wall room 113
- Install one double duplex receptacle on front wall room 113
- Build wall shelving on wall room 114
- Install carpet in room 113, 114, two adjoining offices in 114
- Point trim only room 113, office, 114 and office, 115 office
- Furnish and install two new steel doors with 5x26 glass and deadbolt in room 116
- Remove sink unit in office room 113 and stationary desk
- Plans, diagrams and specs
- Tile raised floor in 116 with blue tile
- Install one entrance lock on door in room 114
- Remove old water line in room 113



NOTES:

1 - ALL "A" & "B" CIRCUITS ARE TYPICAL
2 - ALL CONDUIT WILL BE 3/4" THROUGH SLAB
3 - ALL CIRCUIT'S WILL BE 4-WIRE #12 COPPER
4 - ALL CIRCUIT'S WILL HAVE 20 AMP BREAKER'S
5 - RECEPTICAL'S IN LECTURE ROOM FLOOR TO BE FLUSH
6 - RECEPTICALS ON WALL'S CAN BE WIRED FROM FLOOR OR CEILING
7 - CONDUIT FOR INTER-NET CONTINOUS & STUBBED 4" ABOVE FLOOR
8 - SECURITY SYSTEM AS LISTED BELOW
- 6 DUAL MICROWAVE & INFRARED SENSOR'S
- 2 40 WATT SPEAKER'S
- 2 TAMPER PROOF BOXES
- 1 8 ZONE PANEL W/DIGITAL COMMUNICATOR, BATTERY CHARGE & KEED OPPRON SWITCH
- 1 - 7 AH BATTERY & MISC. MATERIAL'S

TYPICAL TYPE "A" BOX

JOB: INSTALLATION OF ATM NETWORK TO THE DESKTOP IN LESTER HALL

CONTRACTOR: ADNET SYSTEMS, INC.

SCOPE OF WORK:

Details provided on the following pages.

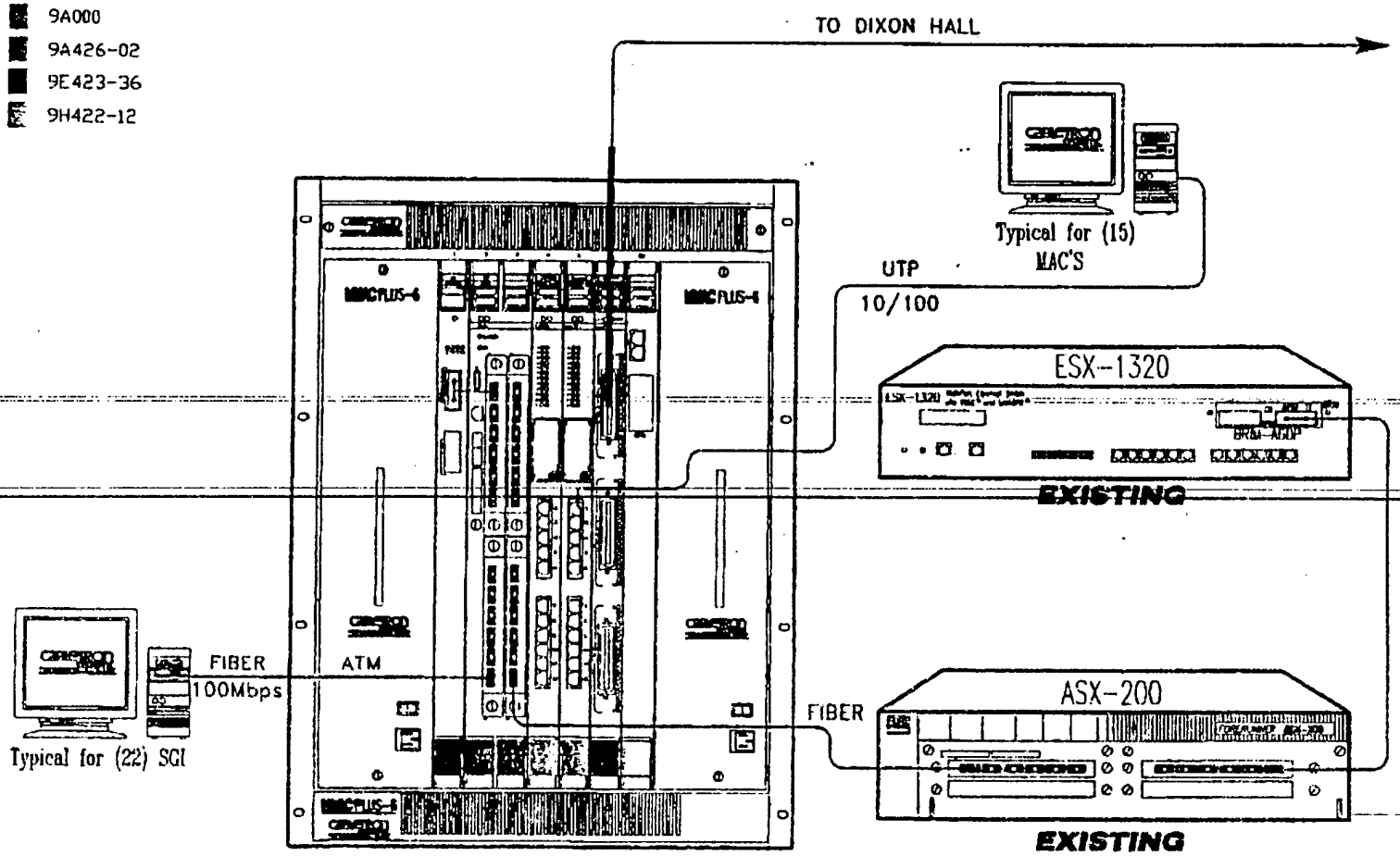
Section II

- LAN Diagrams
- Engineer's Report

ELIZABETH CITY STATE UNIVERSITY
LESTER HALL

MMACPlus-6 Module Legend

- 9A000
- 9A426-02
- 9E423-36
- 9H422-12



Cable Legend

- Unshielded Twisted Pair
- Shielded Twisted Pair
- Fiber Optic
- AUI
- Wide Area Link
- Coax

Graphics NW
EXPRESS CAD!

Proposed For: ELIZABETH CITY STATE UNIVERSITY			
Location: ELIZABETH CITY, NC			
Date: 10/21/96	Drawn By: KJL	Sheet No. 1 of 1	
Filename: 1F_OF4Y	Proposal No. EX102196KJ	Rev: 0	

cabletron SYSTEMS
The Complete Networking Solution™

The Building of Asynchronous Transfer Mode Elizabeth City State University ONR ATM Report 1997

Introduction

The growing number of users and increasingly sophisticated client-server applications need more network capacity than the current technologies provided. Today new and more complex, multimedia applications, with their mix of graphics, audio and video, are creating a demand for greater and faster network topology.

ATM provides the needed bandwidth that will allow for full-motion video and audio conferencing that will be implemented at Elizabeth City State University, Network Resources and Training Site, located in Lester Hall room: 115.

Phase 1

The first stage in implementing ATM at Elizabeth City State University, ONR was to study ATM topology, and address both current and future needs by allowing for expansion at a later date.

Asynchronous Transfer Mode is still new to the Local Area Network and Wide Area Network. At the ONR at ECSU it was wise to implement ATM as a small Network testbed to simplify the learning process and minimize the complexity of problem solving. Designing and planning the network configuration was carefully monitored so over designing the network would not be a costly mistake.

The implementation of ATM in Lester Hall would call for ATM to eventually reach all wiring closets in the building. This meant an ATM workgroup switch for the main wiring closet and Ethernet switches with ATM uplinks would provide the backbone connectivity in the Ethernet environment. Shared Ethernet will still play a major role in the network design.

Questions that the ATM Testbed resolved for the ONR project were as follows:

- Who will use the Network?
- What load will each user place upon the network?
- What individual growth is anticipated?
- What media will be needed to accommodate the ATM network?
- And the most important question was, what other networks must connect to the network?

Phase 2.

Phase 2 consisted of designing the main Distribution Frame and setting specifications for the fiber optics which was to be installed from the Telecommunications Center. There are specifications for the maximum tension and minimum bend radius for each fiber optic cable. These specificatations were important for the contractor who would install the underground fibers. Since there is no problem with electromagnetic interference in fiber optic transmission, cable routing near power sources were no problem. The next task was getting a qualified contractor to do ground excavation required to lay the conduits and install fiber optic lines from the Telecommunications Center located on ECSU to Lester Hall, Main Distribution Frame.

Phase 3.

Phase 3 consisted of terminating the Fiber Optic inter-building fiber optic cables in the Main Distribution Frame and running series of test to insure that each fiber optic cable was not under stress and the acceptable DB loss was in range to specification. Fiber Optic power meters were used to measure the optic loss.

Phase 4.

Phase 4 consisted of purchasing and implementing ATM hardware. There were several vendors who were selling ATM equipment. Cabletron products were selected. Specifications were set and the implementation of the hardware was under way. This list follows below :

- Fore System ATM Interface Cards, model, GIA 200 with SC connector station adapters in (10) Silicon Graphic Workstations (SGI).
- Cabletron ASX-200 16 port Switch
- Cabletron ESX1320 Ethernet to ATM switch
- (12) 62.5/125 duplex micron fiber optic cables were installed with ST to SC connector assemblies in the Network Resource Training Site, Lester Hall room: 115.

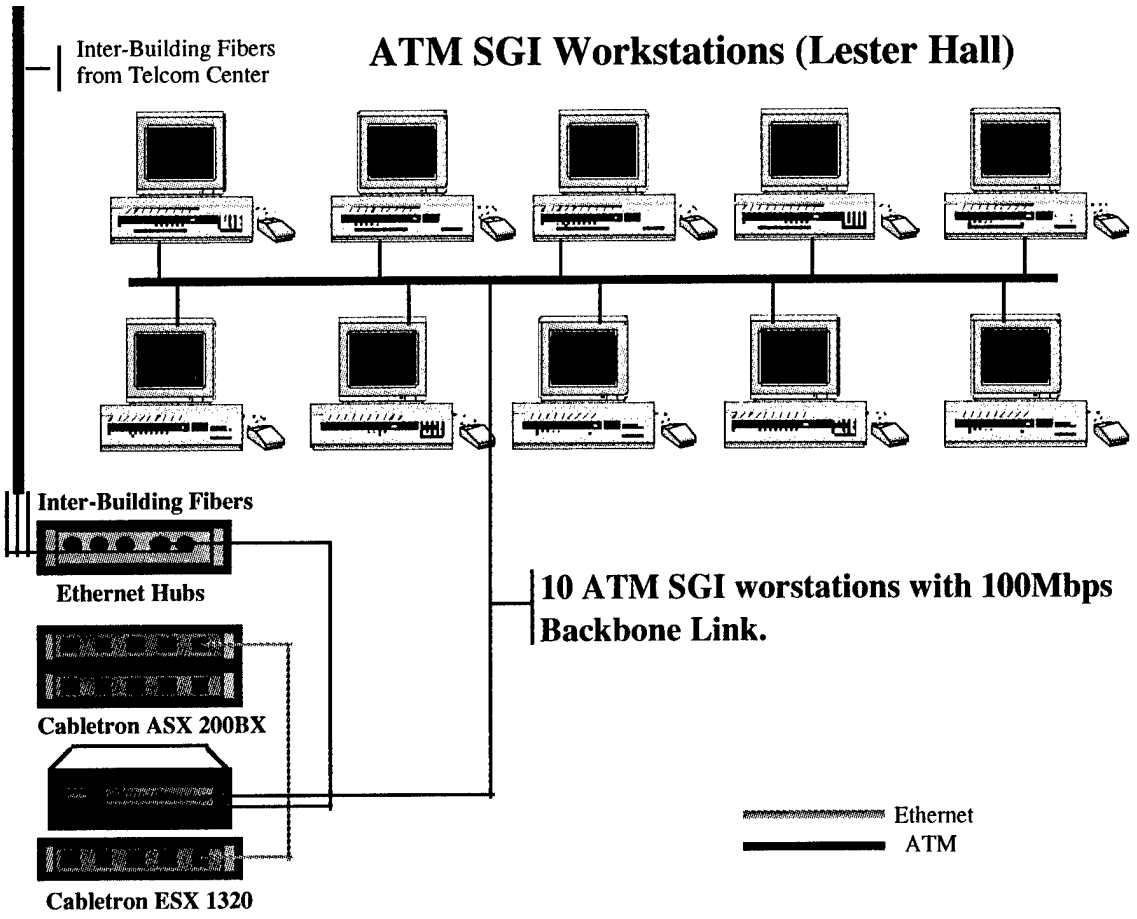
Phase 5.

The next phase was to install fiber optic cables to the desktop. 62.5/125 micron fiber optic cables were in stalled from the Main Distribution Frame to the 10 ATM testbed workstations in Lester Hall room: 115. All fiber optic cables were installed using ST to SC connector. Each optic cable was tested for acceptable DB loss, using optical power meters.

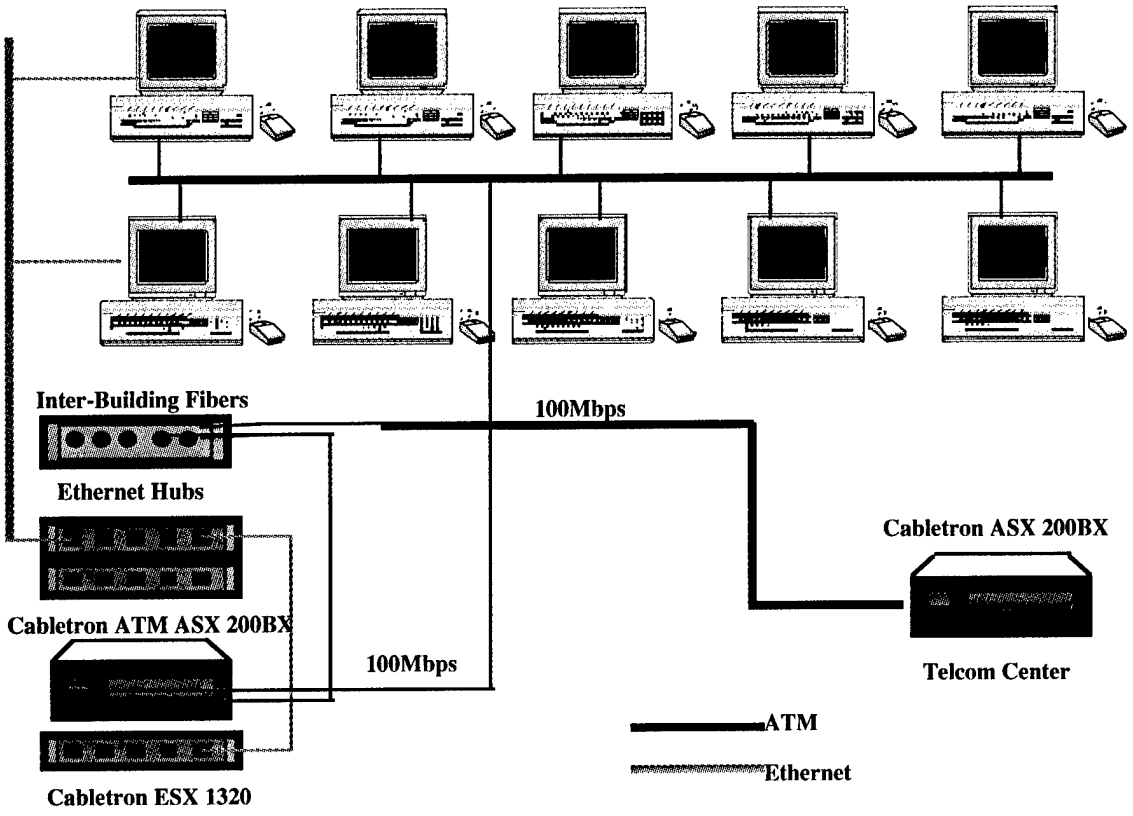
Phase 6.

As mentioned before, Asynchronous Transfer Mode is still new to the Local Area Network and Wide Area Network. Many considerations had to be made in implementing ATM as a true Network Backbone in Lester Hall. The major factor was purchasing a high performance router and the second was subnetting IP address so both ATM and Ethernet would communicate with each other, also providing redundancy if one of the networks should fail.

Making major subnetting changes to the existing Ethernet IP address to make room for the new ATM IP address was not recommended to do in the middle of the semester, and was not recommended by the academic department. The major subnetting will be completed during the summer.


Inter-Building Fibers
from Telcom Center
ATM SGI Workstations (Lester Hall)
Inter-Building Fibers
Ethernet Hubs
Cabletron ASX 200BX
Cabletron ESX 1320
10 ATM SGI worstations with 100Mbps
Backbone Link.
Ethernet
ATM

ATM/Ethernet SGI Workstations (Lester Hall)



ATM Coming to Life (Testbed)

In order to perform the tests which are necessary to achieve the goals of reaffirmation, the research team conceived a testbed. A testbed consists of the hardware and software required to verify the team's theory that ATM is the better means of data delivery and retrieval. The information that is recovered from the testbed will be obtained through benchmark testing. Benchmark testing measures the performance of a system or a subsystem on a well-defined task or set of tasks. These tests are utilized in three ways: to predict performance, to ensure the minimum performance in a procurement specification, and as monitoring and diagnostic tools. By employing the elements necessary the research team will undoubtedly reinforce the notion that ATM is a faster more efficient means of data retrieval and delivery than Ethernet.

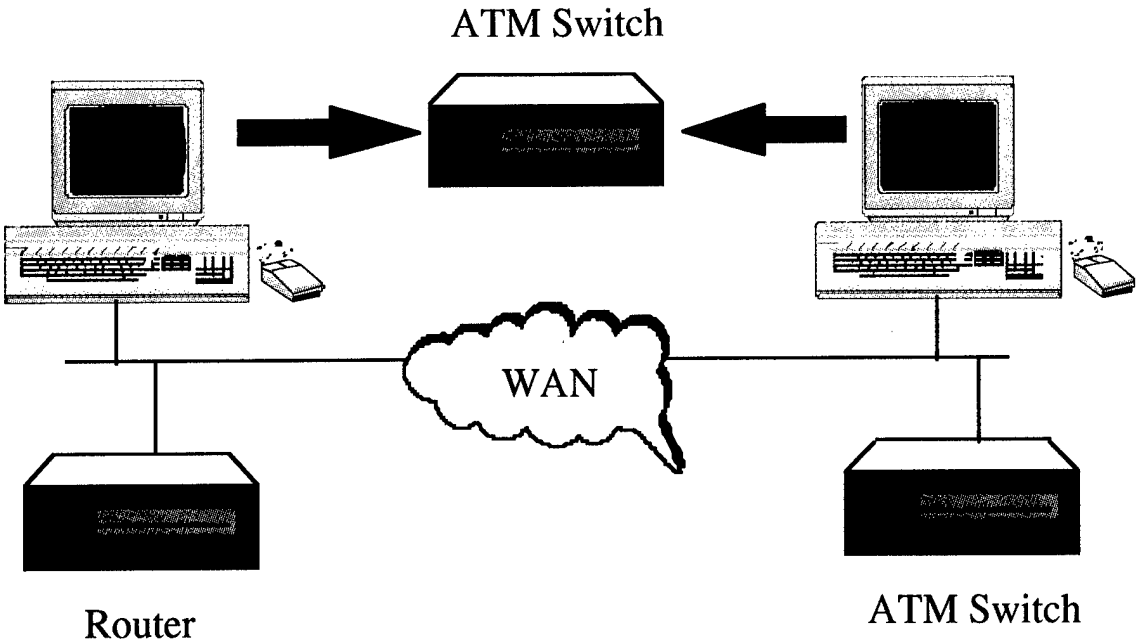
In order for the System Administration/Networking team to make a logical comparison to ATM, a testbed had to be defined. A testbed includes the hardware, software, test tools, and environment, all of which are necessary in conducting tests. A well devised testbed will ensure all of the needed materials are readily accessible. The following paragraphs will define the ATM testbed.

One component of a testbed is the actual hardware used. Hardware consists of any physical equipment such as workstations, switches, hubs, and various other devices. Our testbed consists of an ATM Switch, Ethernet Hubs, an Ether Switching Hub, Fiber Distribution Centers, and Silicon Graphic workstations with ATM Cards.

The next component of the testbed is the software being used. The software includes the operating system, applications, or test tools. IRIX 5.3 is the operating system being used and InPerson is the software application for desktop video conferencing. The test tools are used to test the software or equipment the researcher is using. Two examples of test tools are Netperf (Network Performance) and TTCP (Testing Transmission Control Protocol). Netperf and TTCP are benchmarks that can be used to measure various aspects of networking performance. Currently, their focus lies in determining UDP (User Data Protocol) or TCP (Transmission Control Protocol) performance between two systems.

Finally, the environment is an important component of the testbed. This will be the place where most, if not all, of the testing will be conducted. An environment can range from a lab to an office. For instance, the environment in Lester Hall consists of a communication closet which includes an ATM switch, Ethernet Hubs and switches along with a computer lab consisting of SGI workstations.

ECSU-SA/ATM Testbed



Benchmarking

Using software to retrieve data about hardware components, is commonly referred to as benchmark testing. To better understand benchmark testing, we must first formally define the term. A benchmark is a point of reference from which measurements are made. In computer science, "A benchmark is a test that measures the performance of a system or a subsystem on a well-defined task or set of tasks."

Benchmarks are commonly used in three ways: to predict performance, to ensure the minimum performance in a procurement specification, and as monitoring and diagnostic tools. Benchmarks can predict the performance of an unknown system from the results of a known system. By running benchmarks and comparing the results against a known configuration, one can potentially pinpoint the cause of poor performance. Similarly, a developer can run benchmarks after making a change that can effect performance. Benchmarks can measure graphics, input/output, computations on integers and floating points, and communication performances. Most benchmarks measure specific tasks which include rendering polygons, reading and writing files, and performance operations on matrices.

ATM Testbeds

The NCSA/UTRC testbed consisted of 2 Fore Systems switches, a Sun SPARCstation, and SGI Indigo workstations. The testbed configuration was that of a Sun SPARC workstation and a SGI Indigo connected to an Fore ASX-100 switch. The testing software used was nettest. Nettest measures memory to memory transfer of data, therefore making it a more accurate estimate of network throughput. The nettest options used were packet size, transport layer protocol, window size, and the number of packets sent. The results concluded that the average read throughput (performance measurements for reading data sent from the SGI) was 11 Mb/s and the average write throughput (throughput on write operations from the Sun to the SGI) was 40 Mb/s.

To test the accuracy of your test you must have tests to compare them with. To compare the tests, both your tests and your test tools and theirs must be identical or very close. If not, your results will not be very accurate. In a test found from IAIK, they

were testing the ATM TCP (transmission control protocol) performance of different workstations such as ULTRA SPARC, SPARCstation 10/512, and a SGI Power Challenge. The achieved throughput is compared to the theoretical limit which is about 135 Mb/s when reducing the bitrate of a 155Mb/s OC3 link by the SONET overhead, the AAL5 overhead, and the ATM cell overhead. In one test between a SPARCstation 10/512 and SGI Power Challenge where the SPARCstation was the machine sending the data and the SGI Power was the machine receiving the data, the measured maximum TCP performance was 60.98 Mbit/s with the percentage of maximum theoretical limit of 45.33%. In another test, ULTRA SPARC was the sender and SGI Power Challenge was the receiver, the maximum TCP performance was 100.73 Mbit/s at a percentage of 74.88

Ethernet Test Results

The System Administration/ ATM Networking Team used TTCP (which was found on the internet) to test the Transmission Control Protocol (TCP) over Ethernet from Indy to Indy. TCP is a "standardized transport protocol developed for interconnection IP-based networks." TTCP times the transmission and reception of data between two systems using TCP or UDP (user datagram protocol).

In order to run TTCP, it was compiled as you would any C program, so it could use the a.out file. Then the receiver started with a.out -r -s followed by the transmitter using a.out -t -s plus the name of machine receiving the data.

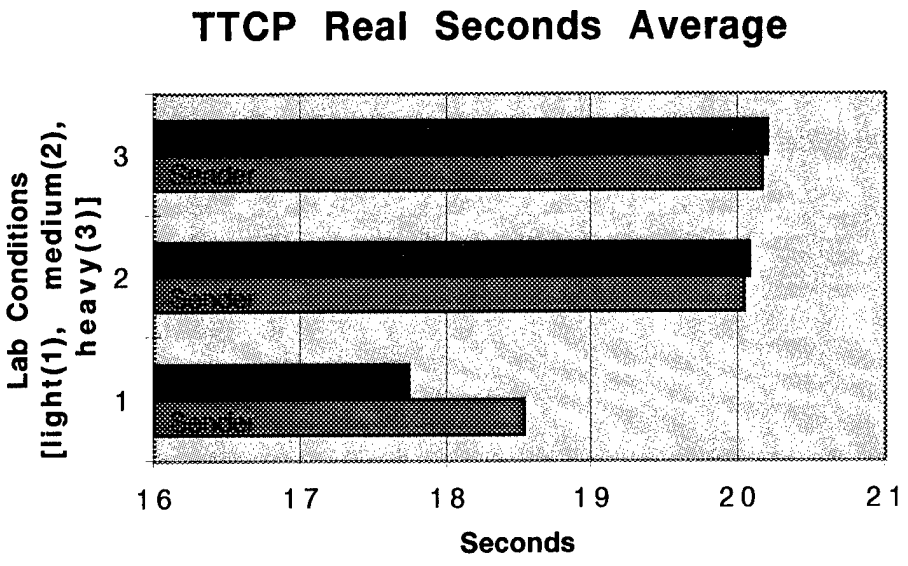
-t = transmit mode
-r = receiver mode
-s = if transmitting a data pattern to network
and if receiving sink (to discard the data).
Otherwise it will transmit data from stdin
or print received data to stdout.

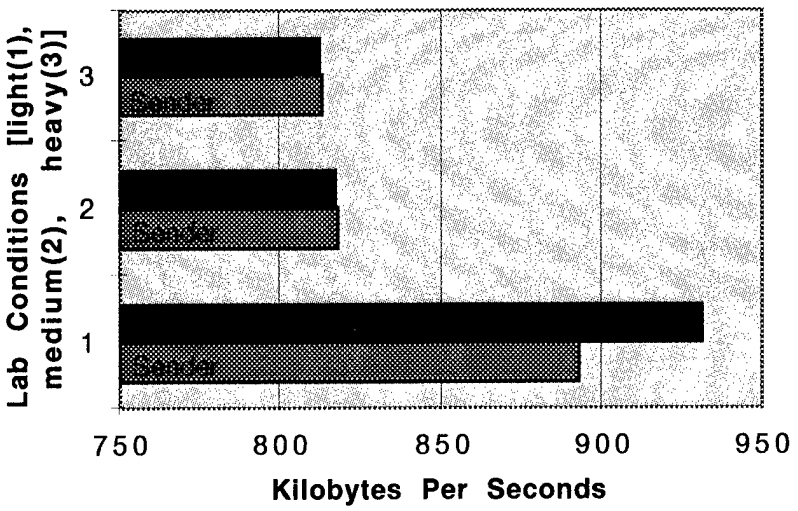
During the TTCP test, simulations of Light, Medium, and Heavy Network ultilization was averaged and graphed in Real Seconds and Kilobytes/Seconds.

Note: There may be some discrepancy in our results due to events beyond our control.

TTCP.C INDY TO INDY TEST RESULTS CHART			
	AVERAGE		
	LIGHT	MEDIUM	HEAVY
SENDER			
REAL SECOND	18.53	20.04	20.16
KB/SEC	892.91	817.48	812.99
RECEIVER			
REAL SECOND	17.73	20.07	20.19
KB/SEC	931.25	816.67	811.70

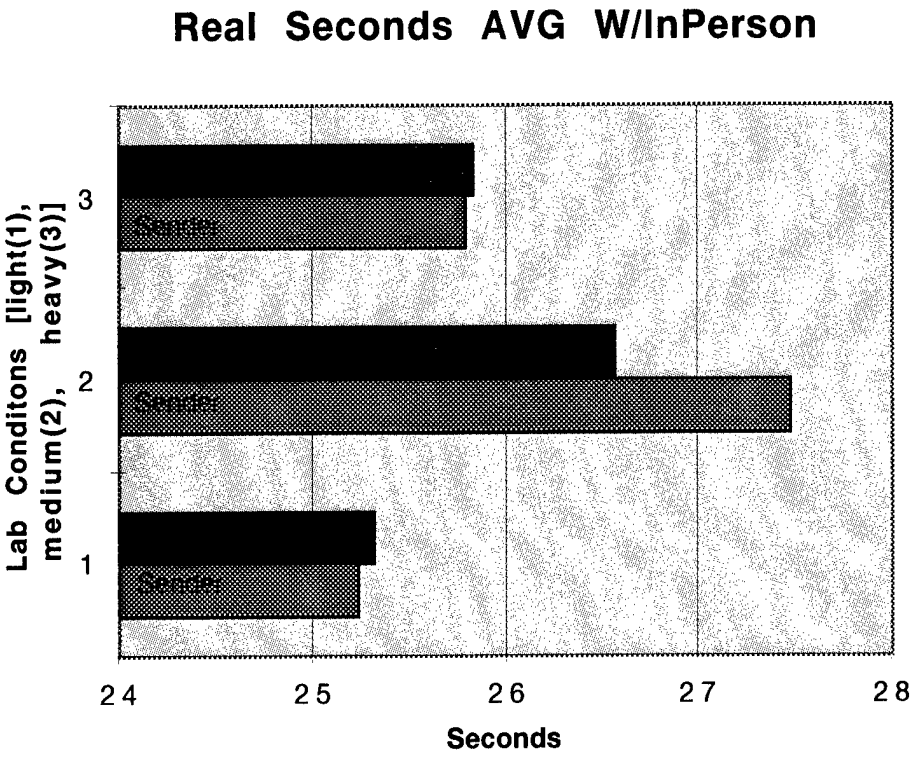
Looking at the data above for both the sender and receiver, as the real seconds increase under the different lab conditions (light, medium, and heavy), the kilobytes/seconds decrease. The bar graphs below show the results of TCP in real seconds and kilobytes/second between the sender and receiver in relation to the lab conditions.

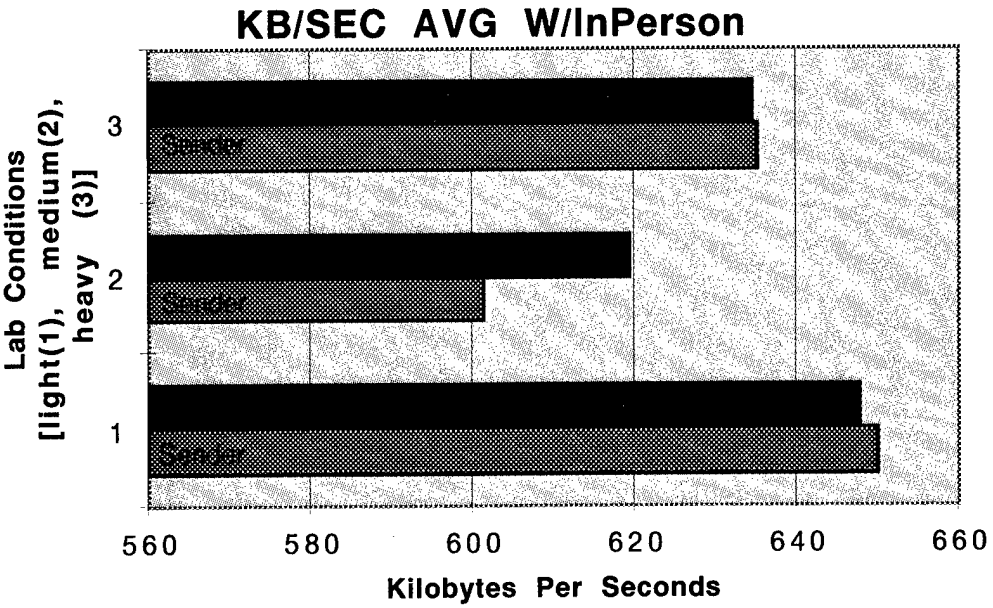




TTCP INDY TO INDY TEST RESULTS AVERAGE RUNNING INPERSON			
	Light	Medium	Heavy
SENDER			
Real Second	25.23	27.47	25.79
KB/Sec	649.98	601.23	635.23
RECEIVER			
Real Second	25.31	26.56	25.83
KB/Sec	647.81	619.47	634.45

The data above is from the TTCP test that was run while using InPerson. Below are the bar graphs of real seconds and kilobytes/second, that the test results found.





The test results show how the transmitter and receiver transmission control protocol data transferring rate varies under different conditions. Some of the conditions that affect the rate of data being transferred are the number of people in the lab, the number of processes being run on the system, and how many packages are being sent during testing. After comparing both ATM and Ethernet test results, you can see that ATM transmission rate is faster than Ethernet's transmission rate.

Conclusion

As ATM is becoming a leading technology in the field of computer science, more and more people are pursing new avenues in which to advance ATM and its technology even further. But in order to accomplish this, tests have to be run to ensure the capability and compatibility of ATM to a specific network.

Within the tests, Ethernet was used to run tests using our current networking setup. These test results were compared to the ATM test results that were obtained. These test results yielded that ATM was faster than Ethernet. The next steps include implementing the same tests that were run with Ethernet on ATM. We will begin this phase of our report when ATM is implemented within our computer science

department. In conclusion, ATM will be fully tested when the subnetting of the IP address are completed during the summer.

Section III

- *Final Report Required Forms*
  - *Report Documentation Page*
  - *Equipment Purchases for Grant*
  - *SF 269*
  - *Report on Inventions and Subcontracting*

REPORT DOCUMENTATION PAGE

FORM APPROVED
OMB No. 0704-0188

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		Final Report

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6. AUTHOR(S)

Dr. Linda B. Hayden

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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1704 Weeksville Road
Elizabeth City NC 27909

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Office of Naval Research

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Unlimited

12b. DISTRIBUTION CODE

N00179

13. ABSTRACT (Maximum 200 words)

This report documents the efforts to bring ATM Network Technology to the desktop workstations located in Lester Hall on the Campus of Elizabeth City State University. The report contains the "scope of work" document submitted by Adnet, Inc. the 8(a) company hired to install ATM, as well as Adnets final report. Upgrades to the physical plant (Swimme contractors) and electrical upgrades (Watson Electrical) are also documented in this report. Finally a copy of the ATM Networking Team of undergraduates and Computer Visualization Team Reports is attached.

14. SUBJECT TERMS	15. NUMBER OF PAGES:
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT:	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT

ONR-ECSU INSTRUMENTATION FOR EDUCATIONAL USE		
EQUIPMENT PURCHASES FOR GRANT #N00014-95-1-1242		
EQUIPMENT ITEM	MANUFACTURER	COST
QMS Magicolor color laser copier	Magicolor	$6,357.00
Canon Typewriter	Canon	621.17
Keyboard and Mouse	Minicomputer Exchange	221.66
Video Editor,Image Processor, Sima Edlit	Damark	729.97
Blue folding tables, 36"x72" (6)	American Academic Suppliers	
Mobile teacher's chairs brown and blue (20)	American Academic Suppliers	1,117.60
Round Blue Tables 48" (6), Springer Penguin (2)	American Academic Suppliers	1,251.56
Macintosh Performa 636, Color Stylewriter,	Apple	3,903.76
Apple Multiple Scan15", Powerbook 5300/100		
Ethermac AAUI to 10BASE-T Transceiver	MacWarehouse	212.70
Computer Desk, PC Workstation with Printer	UARCO	603.02
Cart, Overhead Storage Hutch		
AP-8820 Fastblazer Rm Modem, 19" Chassis	Access Networks	6,558.00
RD 1802 Power Supply, Equipment Rack		
SGI Indy2 & presenter	Silicon Graphics	109,883.30
ATM networking parts	Cabletron	57,491.91
TOTAL		$188,951.65

COPY

Elizabeth City State University
1704 Weeksville Road
ELIZABETH CITY, NORTH CAROLINA 27909

OFFICE OF THE CONTROLLER

TEL: (919) 335-3211
FAX: (919) 335-3539

May 13, 1997

Mrs. Patricia A. Stevenson
Grant Specialist
Office of Naval Research
Atlanta Regional Office
100 Alabama Street NW, Suite 4R15
Atlanta, Georgia 30303-3104

Dear Mrs. Stevenson:

Enclosed are our Request for Reimbursement (SF270) and our Final Financial Status Report (SF269) for Grant N00014-95-1-1242.

Should you have questions concerning these documents, please contact me at (919) 335-3210.

Cordially,

Linda J. Spence

Linda J. Spence
Contracts and Grants

LJS/bs

cc: Mr. Dan E. Anekwu
Dr. Linda Hayden

Enclosure

1. Federal Agency and Organizational Element to Which Report is Submitted	2. Federal Grant or Other Identifying Number Assigned By Federal Agency	OMB Approval No.	Page	of
Office of Naval Research	N00014-95-1-1242	0348-0039	1	1 pages

3. Recipient Organization (Name and complete address, including ZIP code)
Elizabeth City State University
1704 Weeksville Road
Elizabeth City, NC 27909

4. Employer Identification Number	5. Recipient Account Number or Identifying Number	6. Final Report	7. Basis
56-104-7680	552563	☒ Yes ☐ No	☒ Cash ☐ Accrual

8. Funding/Grant Period (See instructions) From: (Month, Day, Year)	To: (Month, Day, Year)	9. Period Covered by this Report From: (Month, Day, Year)	To: (Month, Day, Year)
07/15/95	03/15/97	February 8, 1997	March 15, 1997

10. Transactions:	I Previously Reported	II This Period	III Cumulative
a. Total outlays	296,714.05	375.95	297,090.00
b. Refunds, rebates, etc.			
c. Program income used in accordance with the deduction alternative			
d. Net outlays *(Line a. less the sum of lines b and c)*	296,714.05	375.95	297,090.00
Recipient's share of net outlays, consisting of:			
e. Third party (in-kind) contributions	.00	.00	.00
f. Other Federal awards authorized to be used to match this award	.00	.00	.00
g. Program income used in accordance with the matching or cost sharing alternative	.00	.00	.00
h. All other recipient outlays not shown on lines e, f or g	.00	.00	.00
i. Total recipient share of net outlays *(Sum of lines e, f, g and h)*	.00	.00	.00
j. Federal share of net outlays (line d less line i)	296,714.05	375.95	297,090.00
k. Total unliquidated obligations			.00
l. Recipient's share of unliquidated obligations			.00
m. Federal share of unliquidated obligations			.00
n. Total federal share (sum of lines j and m)			297,090.00
o. Total federal funds authorized for this funding period			297,090.00
p. Unobligated balance of federal funds *(Line o minus line n)*			.00
Program income, consisting of:			
q. Disbursed program income shown on lines c and/or g above			
r. Disbursed program income using the addition alternative			
s. Undisbursed program income			
t. Total program income realized *(Sum of lines q, r and s)*			

11. Indirect Expense	a. Type of Rate *(Place "X" in appropriate box)* ☐ Provisional ☐ Predetermined ☐ Final ☐ Fixed	b. Rate	c. Base	d. Total Amount	e. Federal Share

12. *Remarks: Attach any explanations deemed necessary or information required by Federal sponsoring agency in compliance with governing legislation.*

13. Certification: **I certify to the best of my knowledge and belief that this report is correct and complete and that all outlays and unliquidated obligations are for the purposes set forth in the award documents.**

Typed or Printed Name and Title	Telephone (Area code, number and extension)
Dan E. Anekwu, Controller	(919) 335-3210
Signature of Authorized Certifying Official	**Date Report Submitted**
Dan E. Anekwu	May 9, 1997

Previous Editions not Usable

Standard Form [illegible]

REQUEST FOR ADVANCE OR REIMBURSEMENT

(See instructions on back)

1 | 1 PAGES

1. TYPE OF PAYMENT REQUESTED
a. "X" one, or both boxes: ☐ ADVANCE ☒ REIMBURSEMENT
b. "X" the applicable box: ☒ FINAL ☐ PARTIAL

2. BASIS OF REQUEST: ☒ CASH ☐ ACCRUAL

3. FEDERAL SPONSORING AGENCY AND ORGANIZATIONAL ELEMENT TO WHICH THIS REPORT IS SUBMITTED: Office of Naval Research

4. FEDERAL GRANT OR OTHER IDENTIFYING NUMBER ASSIGNED BY FEDERAL AGENCY: N00014-95-1-1242

5. PARTIAL PAYMENT REQUEST NUMBER FOR THIS REQUEST: INSTR - 10

6. EMPLOYER IDENTIFICATION NUMBER: 56-104-7680

7. RECIPIENT'S ACCOUNT NUMBER OR IDENTIFYING NUMBER: 552563

8. PERIOD COVERED BY THIS REQUEST
FROM (month, day, year): February 8, 1997
TO (month, day, year): March 15, 1997

9. RECIPIENT ORGANIZATION
Name: Elizabeth City State Univ.
Number and Street: 1704 Weeksville Road
City, State and ZIP Code: Elizabeth City, NC 27909

10. PAYEE (Where check is to be sent if different than item 9)
Name: Elizabeth City State University
Number and Street: 1704 Weeksville Road
City, State and ZIP Code: Elizabeth City, NC 27909

11. COMPUTATION OF AMOUNT OF REIMBURSEMENTS/ADVANCES REQUESTED

PROGRAMS/FUNCTIONS/ACTIVITIES ►	(a)	(b)	(c)	TOTAL
a. Total program outlays to date (As of date)	$297,090.00	$	$	$ 297,090.00
b. *Less:* Cumulative program income	.00			.00
c. Net program outlays (*Line a minus line b*)	297,090.00			297,090.00
d. Estimated net cash outlays for advance period	.00			.00
e. Total (*Sum of lines c & d*)	297,090.00			297,090.00
f. Non-Federal share of amount on line e	.00			.00
g. Federal share of amount on line e	297,090.00			297,090.00
h. Federal payments previously requested	296,714.05			296,714.05
i. Federal share now requested (*Line g minus line h*)	375.95			375.95
j. Advances required by month, when requested by Federal grantor agency for use in making prescheduled advances — 1st month				
2nd month				
3rd month				

12. ALTERNATE COMPUTATION FOR ADVANCES ONLY

a. Estimated Federal cash outlays that will be made during period covered by the advance	$
b. *Less:* Estimated balance of Federal cash on hand as of beginning of advance period	
c. Amount requested (*Line a minus line b*)	$

13. CERTIFICATION

I certify that to the best of my knowledge and belief the data above are correct and that all outlays were made in accordance with the grant conditions or other agreement and that payment is due and has not been previously requested.

SIGNATURE OF AUTHORIZED CERTIFYING OFFICIAL: Dan E. Anekwu

DATE REQUEST SUBMITTED: 05/09/97

TYPED OR PRINTED NAME AND TITLE: Dan E. Anekwu, Controller

TELEPHONE (AREA CODE, NUMBER, EXTENSION): (919) 335-3211

This space for agency use

REPORT OF INVENTIONS AND SUBCONTRACTS

(Pursuant to "Patent Rights" Contract Clause) (See Instructions on Reverse Side.)

Form Approved
OMB No. 0704-0237
Expires Jun 30, 1992

1a. NAME OF CONTRACTOR / SUBCONTRACTOR	1c. CONTRACT NUMBER	2a. NAME OF GOVERNMENT PRIME CONTRACTOR	2c. CONTRACT NUMBER	3. TYPE OF REPORT (X one)
Elizabeth City State U	N00014-95-1-1242			a. INTERIM [ ] b. FINAL [X]
1b. ADDRESS (Include ZIP Code)	1d. AWARD DATE (YYMMDD)	2b. ADDRESS (Include ZIP Code)	2d. AWARD DATE (YYMMDD)	4. REPORTING PERIOD (YYMMDD)
1704 Weeksville Road Elizabeth City NC 27909	95-07-15			a. FROM 95-07-15 b. TO 97-03-15

SECTION I – SUBJECT INVENTIONS

5. "SUBJECT INVENTIONS" REQUIRED TO BE REPORTED BY CONTRACTOR / SUBCONTRACTOR (If "None," so state)

a. NAME(S) OF INVENTOR(S) (Last, First, MI)	b. TITLE OF INVENTION(S)	c. DISCLOSURE NO., PATENT APPLICATION SERIAL NO. OR [illegible]	d. ELECTION TO FILE PATENT APPLICATIONS (1) United States (YES / NO)	d. (2) Foreign (YES / NO)	e. CONFIRMATORY INSTRUMENT OR ASSIGNMENT FORWARDED TO CONTRACTING OFFICER [illegible]
None					

f. EMPLOYER OF INVENTOR(S) NOT EMPLOYED BY CONTRACTOR / SUBCONTRACTOR		g. ELECTED FOREIGN COUNTRIES IN WHICH A PATENT APPLICATION WILL BE FILED	
(1) (a) Name of Inventor (Last, First, MI)	(2) (a) Name of Inventor (Last, First, MI)	(1) Title of Invention	(2) Foreign Countries of Patent Application
N/A	N/A		
(b) Name of Employer	(b) Name of Employer		
(c) Address of Employer (Include ZIP Code)	(c) Address of Employer (Include ZIP Code)		

SECTION II – SUBCONTRACTS (Containing a "Patent Rights" clause)

6. SUBCONTRACTS AWARDED BY CONTRACTOR / SUBCONTRACTOR (If "None," so state)

a. NAME OF SUBCONTRACTOR(S)	b. ADDRESS (Include ZIP Code)	c. SUBCONTRACT NO.(S)	d. DFAR "PATENT RIGHTS" (1) Clause Number	d. (2) Date (YYMM)	e. DESCRIPTION OF WORK TO BE PERFORMED UNDER SUBCONTRACT(S)	f. SUBCONTRACT DATES (YYMMDD) (1) Award	f. (2) Estimated Completion
None							

SECTION III – CERTIFICATION

7. CERTIFICATION OF REPORT BY CONTRACTOR / SUBCONTRACTOR (Not required if [ ] Small Business or [X] Non-Profit organization.) (X appropriate box)

a. NAME OF AUTHORIZED CONTRACTOR / SUBCONTRACTOR OFFICIAL (Last, First, MI)	c. I certify that the reporting party has procedures for prompt identification and timely disclosure of "Subject Inventions," that such procedures have been followed and that all "Subject Inventions" have been reported.	
b. TITLE	d. SIGNATURE	e. DATE SIGNED

DD Form 882, OCT 89 — *Previous editions are obsolete.* — 971284

Section IV

- *Undergraduate Research Team Reports*
- *ATM Network Team Report*
- *Computer Visualization Team Report*

System Administration/ATM Networking Team

Final Report April 24, 1997

Mentors:
Dr. Linda Hayden
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Melvin Anderson
Derrek Burrus
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Table of Contents

ABSTRACT

Asynchronous Transfer Mode (ATM) is a connection-oriented transmission protocol, based on fixed-length cells of 53 bytes. ATM is predominantly utilized as a means of solving network inefficiencies while increasing the productivity of the network's users. Developed in the United States by Bellcore Laboratories, ATM serves as a means of communication between both Local Area Networks (LAN) and Wide Area Networks (WAN). The System Administration/ATM Networking research team at Elizabeth City State University will attempt to reaffirm the theory that ATM is a faster and more efficient means of network communication than Ethernet.

In order to perform the tests which are necessary in achieving the goals of reaffirmation, the research team must conceive a testbed. A testbed consists of the hardware and software required to verify the team's theory that ATM is the better means of data delivery and retrieval. The information that is recovered from the testbed will be obtained through benchmark testing. Benchmark testing measures the performance of a system or a subsystem on a well-defined task or set of tasks. These test are utilized in three ways: to predict performance, to ensure the minimum performance in a procurement specification, and as monitoring and diagnostic tools. By employing the elements necessary the research team will reinforce the notion that ATM is a faster more efficient means of data retrieval and delivery than Ethernet.

Introduction

In today's rapidly advancing technological world, the delivery and retrieval of data becomes critical in the world of computer networking. One of the ways network managers are trying to keep up with endusers demands for rapid transfer of data, is to provide them with high bandwidth. To provide high bandwidth, network managers are exploring the capabilities of Asynchronous Transfer Mode (ATM). Our research will explore the essential elements required in comparing both ATM and Ethernet while analyzing results yielded from our testing. This will further support the existing theory that ATM is a faster and more proficient means of data delivery than Ethernet.

Overview

ATM

ATM is defined as a connection-oriented transmission protocol, based on fixed-length cells of 53 bytes. It is a means of communication used for both Local Area Network (LAN) and Wide Area Network (WAN) technologies. A LAN is a network which interconnects PC's, terminals, workstations, servers, printers and other peripherals at a high speed over short distances. An example of a LAN is a computer lab within a building. A WAN is a network which connects users across large distances often crossing the geographical boundaries of cities and states. An example of a WAN is a group of buildings on a campus interconnected.

The origin of ATM cannot be linked to a particular group. It is said in the United States, Bellcore Laboratories were the first to propose the ideas behind ATM. While in Europe, several large telecommunication companies were developing their own ideas for ATM.

Being the "new technology on the block" everyone is trying to utilize it in various applications. Therefore, standards must be set on how it is to be used to the extent of its networking capability. The foremost group handling issues such as this is the ATM Forum. The ATM Forum is a consortium of organizations representing vendors, manufacturers, carriers, service providers, universities, research groups, consultants and users that make recommendations and define specifications for ATM. The ATM Forum also promotes industry cooperation in the implementation of ATM technologies to transfer packets across both private and public networks, and encourages the development of products that involve the use of ATM technologies.

The ATM Forum is currently looking for more prevalent areas in which to expand ATM. One of the major aspects that would allow many of these expansions to take place is the use of emulation. Emulation is a technology that allows excess bandwidth within network lines to be used therefore, maximizing the transferal of data between two existing points. By using emulation more data can be sent or received than by using regular data transmission methods. Without emulation, waiting for bandwidth within a network line to be allocated for use could bring up the possibility of the loss of bits, resulting in the loss of packets, which ultimately results in the loss of data.

The use of emulation in ATM gives it an advantage over other networking protocols by allowing transmission of data from point to point to travel faster. With technologies such as this, ATM is beginning to be used for more tasks. Multimedia servers are becoming feasible because of this and the standards associated with it. Transmission of other data such as voice is also becoming possible with the use of ATM for companies, universities, etc.

Another new use of ATM is video conferencing. Video conferencing is a discussion between two or more groups of people who are in different places but can see and hear each other using electronic communications. Sound and pictures are carried by a telecommunication network such conferences can take place across the world. With the help of ATM, video conferencing allows the user to communicate with other users as if they were standing face to face.

Testbed

In order for the System Administration/Networking team to make a logical comparison to ATM, we had to define our testbed. A testbed includes the hardware, software, test tools, and environment, all of which are necessary in conducting tests. A well devised testbed will ensure all of the needed materials are readily accessible. The following paragraphs will define our testbed.

One component of a testbed is the actual hardware used. Hardware consists of any physical equipment such as workstations, switches, hubs, and various other devices. Our testbed consists of an ATM Switch, Ethernet Hubs, an Ether Switching Hub, Fiber Distribution Centers, and Silicon Graphic workstations with ATM Cards.

The next component of the testbed is the software being used. The software includes the operating system, applications, or test tools. IRIX 5.3 is the operating system being used and InPerson is the software application for desktop video conferencing. The test tools are used to test the software or equipment the researcher is using. Two examples

of test tools are Netperf (Network Performance) and TTCP (Testing Transmission Control Protocol). Netperf and TTCP are benchmarks that can be used to measure various aspects of networking performance. Currently, their focus lies in determining UDP (User Data Protocol) or TCP (Transmission Control Protocol) performance between two systems.
Finally, the environment is an important component of the testbed. This will be the place where most, if not all, of the testing will be conducted. An environment can range from a lab to an office. For instance, our environment consists of a communication closet which includes an ATM switch, Ethernet Hubs and switches along with a computer lab consisting of SGI workstations.

Benchmarking

Using software to retrieve data about hardware components, is commonly referred to as benchmark testing. To better understand benchmark testing, we must first formally define the term. A benchmark is a point of reference from which measurements are made. In computer science, "A benchmark is a test that measures the performance of a system or a subsystem on a well-defined task or set of tasks."

Benchmarks are commonly used in three ways: to predict performance, to ensure the minimum performance in a procurement specification, and as monitoring and diagnostic tools. Benchmarks can predict the performance of an unknown system from the results of a known system. By running benchmarks and comparing the results against a known configuration, one can potentially pinpoint the cause of poor performance. Similarly, a developer can run benchmarks after making a change that can effect performance. Benchmarks can measure graphics, input/output, computations on integers and floating points, and communication performances. Most benchmarks measure specific tasks which include rendering polygons, reading and writing files, and performance operations on matrices.

ATM Testbeds

The NCSA/UTRC testbed consisted of 2 Fore Systems switches, a Sun SPARCstation, and SGI Indigo workstations. The testbed configuration was that of a Sun SPARC workstation and a SGI Indigo connected to an Fore ASX-100 switch. The testing software used was nettest. Nettest measures memory to memory transfer of data, therefore making it a more accurate estimate of network throughput. The nettest options used were packet size, transport layer protocol, window size, and the number of packets sent. The

results concluded that the average read throughput (performance measurements for reading data sent from the SGI) was 11 Mb/s and the average write throughput (throughput on write operations from the Sun to the SGI) was 40 Mb/s.

To test the accuracy of your test you must have tests to compare them with. To compare the tests both your tests and your test tools and theirs must be identical or very close. If not, your results will not be very accurate. In a test found from IAIK, they were testing the ATM TCP (transmission control protocol) performance of different workstations such as ULTRA SPARC, SPARCstation 10/512, and a SGI Power Challenge. The achieved throughput is compared to the theoretical limit which is about 135 Mb/s when reducing the bitrate of a 155Mb/s OC3 link by the SONET overhead, the AAL5 overhead, and the ATM cell overhead. In one test between a SPARCstation 10/512 and SGI Power Challenge where the SPARCstation was the machine sending the data and the SGI Power was the machine receiving the data, the measured maximum TCP performance was 60.98 Mbit/s with the percentage of maximum theoretical limit of 45.33%. In another test, ULTRA SPARC was the sender and SGI Power Challenge was the reciever, the maximum TCP performance was 100.73 Mbit/s at a percentage of 74.88%.

Ethernet Test Results

The System Administration/ ATM Networking Team used TTCP (which was found on the internet) to test the Transmission Control Protocol (TCP) over Ethernet from Indy to Indy. TCP is a "standardized transport protocol developed for interconnection IP-based networks." TTCP times the transmission and reception of data between two systems using TCP or UDP (user datagram protocol).

In order to run TTCP, we compiled it as you would any C program so we could use the a.out file. Then the receiver started with a.out -r -s followed by the transmitter using a.out -t -s plus the name of machine receiving the data.

-t =	transmit mode
-r =	receiver mode
-s =	if transmitting a data pattern to network and if receiving sink (to discard the data). Otherwise it will transmit data from stdin or print received data to stdout.

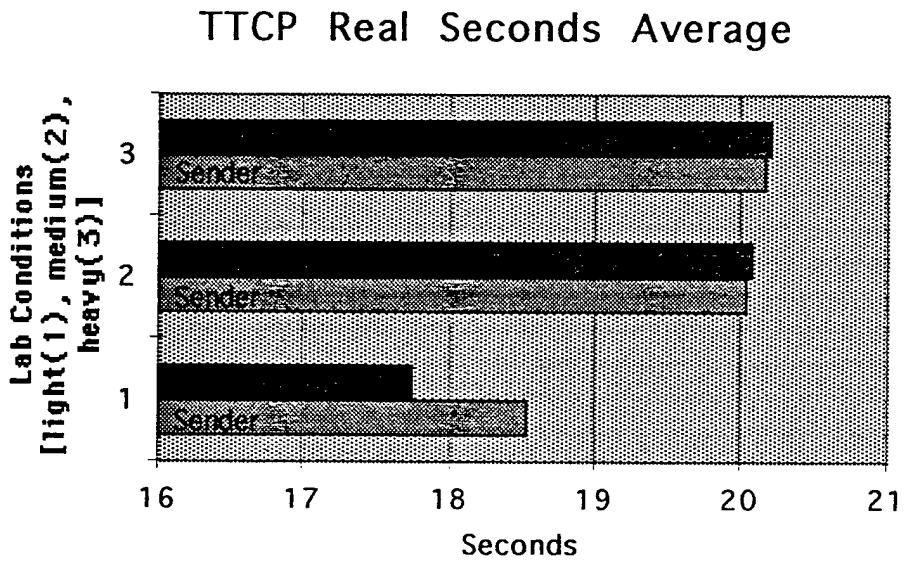
After running our test we took the average of three light, three medium, and three heavy lab conditions. We then graphed the Real Seconds and Kilobytes/Seconds (which is the format of the throughput rate) using Microsoft Excel. In one set of test, we used the

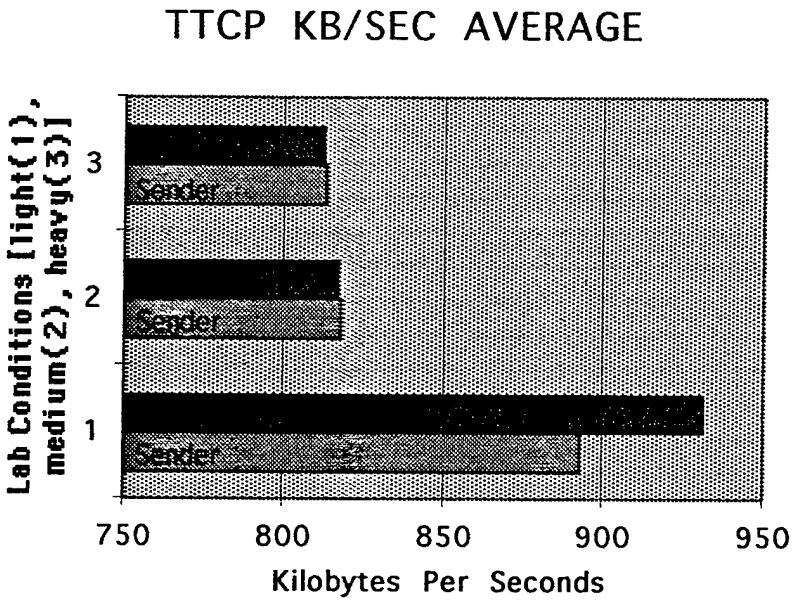
processes being ran on the systems at that time and for the other set we used the processes running with InPerson running also.

Note: There may be some discrepancy in our results due to events beyond our control.

TTCP.C INDY TO INDY TEST RESULTS CHART			
	AVERAGE		
	LIGHT	MEDIUM	HEAVY
SENDER			
REAL SECOND	18.53	20.04	20.16
KB/SEC	892.91	817.48	812.99
RECEIVER			
REAL SECOND	17.73	20.07	20.19
KB/SEC	931.25	816.67	811.70

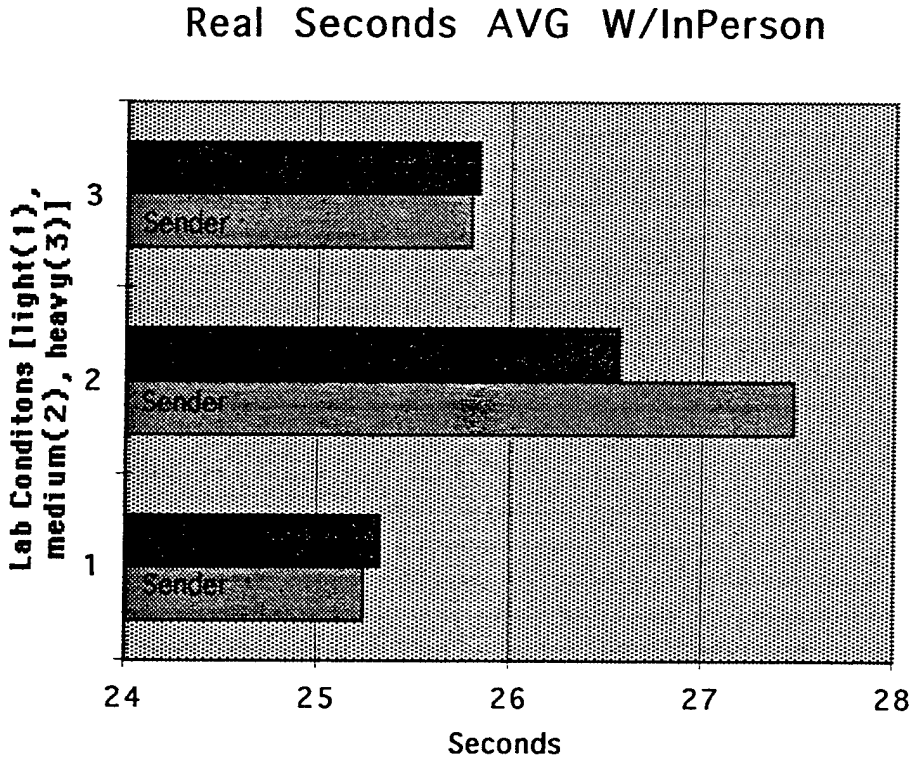
Looking at the data above for both the sender and receiver, as the real seconds increase under the different lab conditions (light, medium, and heavy), the kilobytes/seconds decrease. The bar graphs below show the results of TCP in real seconds and kilobytes/second between the sender and receiver in relation to the lab conditions.

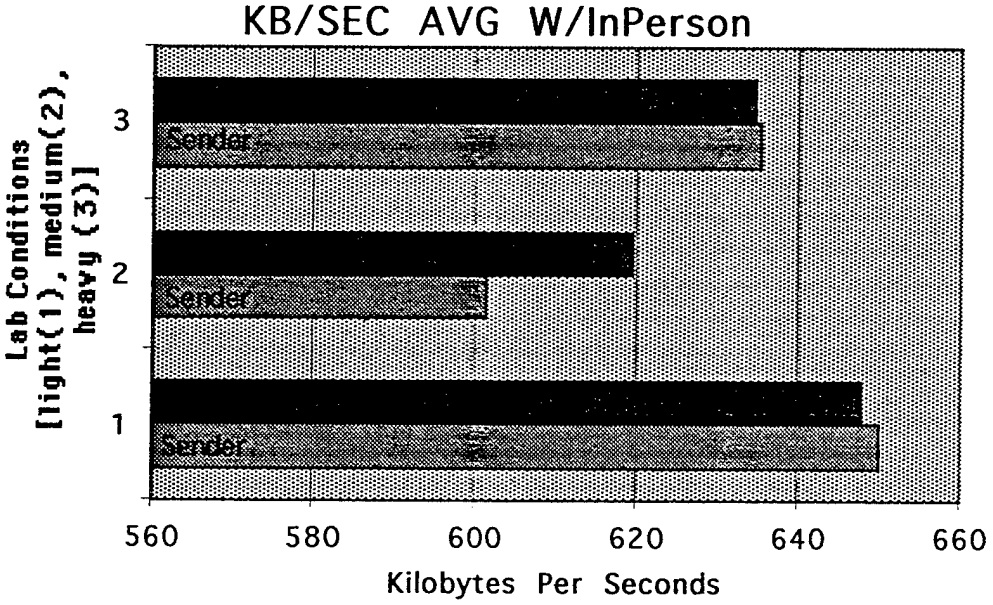




TTCP INDY TO INDY TEST RESULTS AVERAGE RUNNING INPERSON			
	Light	Medium	Heavy
SENDER			
Real Second	25.23	27.47	25.79
KB/Sec	649.98	601.23	635.23
RECEIVER			
Real Second	25.31	26.56	25.83
KB/Sec	647.81	619.47	634.45

The data above is from the TTCP test we ran while using InPerson. Below are the bar graphs of real seconds and kilobytes/second, test results we found.





Our test results, show how the transmitter and receiver transmission control protocol data transferring rate varies under different conditions. Some of the conditions that affect the rate of data being transferred are the number of people in the lab, the number

of processes being run on the system, and how many packages are being sent during testing. After comparing both ATM and Ethernet test results, you can see that ATM transmission rate is faster than Ethernet's transmission rate.

Summary

As ATM is becoming a leading technology in the field of computer science, more and more people are pursing new avenues in which to advance ATM and its technology even further. But in order to accomplish this, test have to be run to ensure the capability and compatibility of ATM to a specific network.

Within our tests, Ethernet was used to run test using our current networking setup. These test results were compared to the ATM test results we obtained. These test results yielded that ATM was faster than Ethernet. The next steps include implementing the same tests that we ran with Ethernet on ATM. We will begin this phase of our report when ATM is implemented within our computer science department. In conclusion, we would be able to fully test and understand the capability of ATM.

Transcript of Conference Call with Adnet, Inc.
The System Administration Team

Sharon Saunders
Kevin Trotman
Kuchumbi Hayden
Curtis Felton, CV
Denisa Edwards, CV

Dr. Hayden: We are starting the recording.
Ashok: We are on the box now. Okay

Dr. Hayden: Yeah. We are on now. Okay. We have some questions for you. Do you have access to the ATM proposal that you submitted?
Ashok: Yes I do. Hold on a second... Okay here we are.

Dr. Hayden: Okay. Lets get some on the terminology straight first. Things like a functional description. What will a typical functional description consist of?
Ashok: A function description is something like... Say your requirement is... do you want to have a bunch of your labs and offices interconnected to each other. And then the office will have a 10baseT setup. And labs will have a ATM or FDDI or what ever have you. A function description will describe that, the functionality, and what that will get you after this job is done. The functionality should have this kind of performance, and it is a guideline for the requirements and what it is you are going to get.

Dr. Hayden: So then we will be able to look at the functional description. And say that we will be able to have, like FTP...
Ashok: Right. For example, functional description for ATM switch and adaptors. Will say what a ATM switch should do. What we will be recommending is what you should purchase. Functionally what specks it should have, how it should function, how many packets it should transmit, and what kind of interface it should have, that kind of stuff. How many ports it should have. So that would be a technical description. In fact, you would take the functional description and based on

that we will say exactly these are the things that we should have. And this is the vendor that we think that you should go with. This will be a very defined and pointed specification.

Dr. Hayden: And when will we be at that stage, after the visit?
Ashok: Well once we come and visit. We will come and take care of things like that, and hopefully we will have our sub-contractor picked out by that time. And then we will go from there and start developing the functional description. Which then we will send it to you. During the visit, we will talk to you and get your ideas and assessment of other people. Who is your vendor that you are leaning towards? And then we can come up with a price. You need that price or you can not speak in terms of acquiring the equipment.

Dr. Hayden: Actually,we needed some information for the bidders on the primes distribution system, they were very much concerned about the number of drops?
Ashok: Okay. That functional description which you're talking about will also have a function description of the PDS, the wiring, and all those things. Which is called cable specification R. Those vendors need to see that. We have that. We have developed most of it. I have not sent you that yet.

Dr. Hayden: There is some indication of preliminary information gathered in the design section, of drops by room and type.
Ashok: Hold on one second.... What section are we talking about?

Dr. Hayden: Page six.
Ashok Page six, okay I am at page six.

Dr. Hayden: The drops by room and type, table that you supplied here. Now the total ATM drops and the total 10baseT drops are a hundred,
Ashok: Yes, 29 plus 71 equals a 100.

Dr. Hayden: Okay. That is pretty much what we came up with when we did our primas distribution walk though also. But one of the vendors gave me a approximate cost of $22,000 as opposed to $18,000. But we can talk about that later.

Ashok: Well actually some of the vendors gave me $30,000.

_____DECISION OF COST DELETED_____

Ashok: Well. You have some concrete you have to drill through.

Dr. Hayden: Maybe, maybe not. We do not have to come through the concrete. We may be able to come though the ceiling. In those cases that would bring the cost down. The second vendor is Charles Ainsley. He is with Sprint Carolina Telephone, and his number is (919)641-3108. I'm going to send you by mail a copy of the diagram that shows the number of drops that we calculated in each room. All right, lets move on to some of the other questions.

Kevin: I what to know what kind of software or protocol changes we are going to have to make on the workstation we have here?

Ashok: On your workstations, all the workstation which you have. The one thing that all workstations should have, UNIX base workstations; you should have TCP/IP in there and you should have ethernet cards in there already. Is not that true? (yes) For PC's you have to have ethernet card, you will need TCP/IP for those machines. There are a couple of ways to go about that. If you already have TCI/IP running on those machines, fine. If you do not, you go head and buy it from commercial vendors, that is one way to do it. Or, you can get a lot of TCP/IP's software from public domain and install it there. Trumphet is a very good product, and another is NCSA, that is also a good one. If you have any question about that. Call the Muspin help desk, they can help you with that. That is what they do, they have a list of all the public domain software and they can also tell you where we can get them. Okay, but that is all that you should have, for high power workstation. What you need is a ATM card that is part of the requirement. And that card should come with the driver software, which will drive the ATM traffic to that card, as far as the workstation goes. And then you will have to make changes in the configuration in Aldus workstation. Because you will be behind a router so that change has to be made, and that will be difficult and we'll take care of that when we get there. When we decide what our address is and how we are going to reconnect it. Those are more in the implementation phase. There will be changes in

the configuration. You will have to modify the workstation and we will be there to help you guys with that.

Kevin: All of our workstations have built in Ethernet interfaces.

Ashok: Well. That is good. Then you do not have to drop in a new card there. You already have ethernet, you just have to configure it differently. You have right now on your workstations. You talking about UNIX base workstations or PC's? (UNIX) UNIX workstations. You already have built in ethernet cards and you probably already have TCI/IP running on those things. Well that is fine. You will continue using that the way it is and you may have to make some changes. We will not know what changes will be made and what we will have to do, untill we actually get to the implementation phase. When we start to implement this thing, and then we have to see what changes we have to make. What ever change it is, it is very simple, its not that complicated. We will give you detailed instructions on how to go about that.

Kevin: On the machines that have built in ethernet interfaces, we will not be able to get maximum through put without using an ATM card, correct?

Ashok: That is right, that's why you have to buy the ATM card, and that card comes with a driver and in your routing, your workstation will have two addresses, one will be for ethernet and one will be for ATM.

Dr. Hayden: We're budgeted for 15 ATM cards at $1400 a piece.

Ashok: That's about right, so what will happen is, take for example, you have an SGI workstation where there is an ethernet card right now that it uses to talk to the campus and on the internet. Then we're going to drop an ATM card there on that workstation. We'll have to open the workstation and drop the card there. Once you drop the card, that card has to be configured and your driver has to be configured properly so that it recognizes that there is another device in the machine and that also has to be defined so that when you are sending ATM traffic, it has to go to the ATM port. As you said, it cannot go to the ethernet port, ethernet is only 14 to 16 bytes, ATM is 52. You know, it is different, different bytes, different

protocol, and different scheme. So it has to go to a different port. Its not that complicated, you know. When we come there we will go over it and we will discuss it, how its going to work and all those things. And as far as configuration goes, its a little tricky, but not impossible. The biggest thing is taking off the chassis and putting in the card and then packing it back as it was.

Kevin: The router that you have in this proposal, you have a router and switches. What is the purpose of the router, is that redundant with the switches and the router that we have in the administration building or is there a purpose for that?

Ashok: Ok, realize what we have here. You do not have to have a router, that goes without saying. You can solve the problem with the switches. Just buy the proper switches, which also then connects to another concentrator and wiring hubs. Which have an interface to connect the switch. You can do away with the router. The reason you have a router here is that you are going to have two networks here. You are going to have one network which will be on ATM, you will have one ATM network and one 10baseT network, you have two separate networks. You can play the fancy games with the switch or the concentrator and have them talk as long as they are on the same class or net address, but if they are different classes of net address; you will need a device such as a router or a smart bridge to pass the traffic between these two LANs. That is why you need to have a router, that's one thing. Secondly, this is a lab that you have, you want to control your lab traffic to the administrative LAN, which I am talking about the campus LAN. So, suppose you're working in the lab and something happens, if you're not behind the router it can go across that LAN to the rest of the campus and it can do some damage. So, by having a router you can control those type of things.

Dr. Hayden: So that's a protection from us for the campus?

Ashok: That's one thing, also the bigger issue here in my mind. You have 15 SGI workstations which will be on ATM, then you will have about 70 that's going to be on your 10baseT. Just think about the physical wiring plan, not the network. Physically

there are two different wiring schemes right there, one is 10baseT and one is your ATM which is fiber. Now these two are two separate networks, but now these two have to talk to each other. There are many ways you can do it. You can put a device at one end. (Conceptually, we are not going into detail.) But you can put a device there, where one end is TP and one end is fiber, and then this guy can interconnect these two LANs. That will work and then you don't need to buy the router as long as you are keeping the same net address. You can do that, but the problem is that you don't have any protection or control of data going out of your LAN or coming to your LAN. That is the difference between a router or say a bridge or concentrator or hub or switch for that matter. A router has a smart net, it controls the controls of data, what goes and what doesn't. A bridge or hub will just take the data and pass it along.

Dr. Hayden: So, we get no control over the data with this router?

Ashok: With a router, yes you do. You get control over who comes into your LAN and who goes out of your LAN and what type of data is coming to you. Also, anytime a LAN is connected to an operational LAN, which the campus will be, the campus is not only going to support math department or the computer science department, but other departments. Once you are connected to an operational lab, and that is what we recommend and again its up to you because ultimately you have to spend the extra money for the router, in a lab where your going to be making changes or whatever where its not an operational environment. You want to have that behind a router or something. If something goes wrong, then you are not destroying the rest of the operational LAN. Secondly, by having a router you are free, then you can make changes in the future. Whether you buy a router today or you buy it a year or two years down the road, you will have to buy a router. I can pretty much guarantee you that.

Kevin: Will they be using fiber obtic line or will they be using twisted pair coming into the labs?

Ashok: Okay. That is a requirement that has been given to us, and that is what we are going by. And if you go and look at page six,

its says that in information gathering and design. Under that, it says drops by room and type. Feel free to make corrections and changes to this if you will. This is what we felt. Is 115 the lab? (yes) we see that 26 under ATM and 116. When we came there and talked to Dr. Hayden thats the number that we got and have, if you have changed since then, we will make changes accordingly. But everything you see under ATM is fiber board. 10baseT is twisted pair as you said.

Kevin: Is there a significant difference in the cost of pulling the fiber as opposed to the coxal?

Ashok: It is different, of course, because you have fibers, you are talking about different kinds of mediums and it is expensive. But not as expensive a cost difference as it used to be.

Dr. Hayden: Mr. Spencer has approached me about having all the cables being fiber.

Ashok: Well, I don't think that you can do that, I am talking about technically. You already have ethernet cards in your workstations. Now, if you pull the fiber and if you bring the fiber, how are you going to connect the fiber to ethernet polls.

Dr. Hayden: There is a possibility of having a combination of fiber and coaxial pulled. That is an expensive endeavor?

Ashok: No. It is not. There is one thing we can do, and its not that expensive, you can have several fibers pulled over, you need to have fiber for ATM with out saying, because ATM will not run over your twisted pair or 10baseT.

Dr. Hayden: Another concentration, because we had to do some shuffling of the SGI money for the network. We are looking at the possibility of having some of our X stations, run of some of our SGI's that we did purchase. And we want to know what considerations we need to be aware of as far as that configuration.

Ashok: Okay, we are talking about X stations. I guess they will be on 10baseT, as far as the network goes. I do not know what extension you are buying from the vendor, and I'm not sure if the X station can take it.

Dr. Hayden: We have not approached any vendor yet. But when we do, what kind of points should we make with him?

Ashok: The most important thing in a X station is how much memory you have. I'm ruff in UNIX. But as far as network is concerned is all X stations should be TCP/IP and ethernet card, you should be fine.

Kevin: What speed will the ATM link be working at, is that a 155 mega byte per second?

Ashok: Yes, that is what it is right now. I do not think you are going to get that one. But it is the best one, and what the vendor would like to give you.

Sharon: Do we need any network detection software, that would detect any errors or anything within the system?

Ashok: Usual ECPI has built in ECPI detection software that you can use to get the primary idea if something is wrong. But we have something that is not on this, but in another proposal that I have worked with Dr. Hayden, during so. We have planned to implement another management center there. That will take care of all of the instances that you have mentioned that will collect all of the data there. It is not part of this work. But it is related work.

Sharon: What additional changes do we need to make to get the maximum output from the ATM lines?

Ashok: That depends on the vendor that you choice for the switch and router and the ATM wiring. The drives and things like that would give you things like that.

"VISUALIZATION OF NASA DATASETS"

OFFICE OF NAVAL RESEARCH

1996-97 COMPUTER VISUALIZATION TEAM

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Abstract

Rapid and extensive advances in three-dimensional computer visualization have been developed and are making a major impact on many industries. The use of three-dimensional viewing has become an essential issue in several academic sectors and the commercial product development. Advanced endeavors are worthless unless the results can be clearly communicated. Meaning, some type of verbal and/or visual medium should be used to interpret the data and to report the results to others.

The 1996-97 Computer Visualization team had the task of visualizing data provided by NASA's Earth Radiation Budget Experiment or ERBE. The ERBE scanner instrument package contains instruments used to measure shortwave, longwave, total waveband radiation, etc. Among all of the data, it was decided to visualize the longwave radiation component between the years of 1984 and 1989.

The software package IRIS Explorer was used to perform the task mentioned above. IRIS Explorer is a visual programming system for data visualization, manipulation, and analysis. The system has a programming component which developers can use to create new applications, and a user environment in which the applications can run. IRIS Explorer runs on Silicon Graphics workstations and is available for other Unix-based workstations and supercomputers.

Introduction

What is computer visualization? It is a graphic representation of numeric data. Visualization involves receiving and interpreting data in order to output a pictorial example of the data. It is used to help researchers interpret numerical data and report their findings. Without computer visualization, advanced science modeling are worthless because they cannot be clearly communicated to others.

There are many software packages that can be used to perform visualization; IRIS Explorer is a system for creating powerful visualization maps, each of which comprises of a series of small software tools called modules. A map carries out a series of operations on a dataset and produces a visual representation of the result. Explorer consists of three main components:

(1) the DataScribe which is a data conversion tool for moving data between IRIS Explorer data format and other data formats,
(2) the Module Builder which lets people create their own custom modules, and
(3) the Map Editor which is a work area for creating and modifying maps.

In order to understand how these components work, one has to understand how a factory works. The purpose of a factory is to take raw materials (numeric data) and shape them into an end product (pictorial representation) according to a specific design. The raw materials are fed into an assembly line at one end, go through a number of alterations and manipulations as they pass through the machines (modules) on the factory floor (Map Editor), and then comes out at the other end in the form of a finished product (visual object or image). The product is inspected for qualities essential to the design; if they are not present or not satisfactory, the machines on the floor can be adjusted (purpose of Map Editor). The Module Librarian displays all available maps and modules. Single modules can be launched by dragging them into the Map Editor. Then they can be connected and wired according to their input and output ports.

DataScribe has three main functions:

(1) to convert data from an external source in ASCII or binary format into IRIS Explorer lattices,

(2) to convert to and from different data types within IRIS Explorer itself, and
(3) to convert data from one file format to another such as from ASCII to binary.

It creates scripts and control panels that can be saved as a module. The new module can be used in the map in order to convert the data to be used.

The Module Builder is used to build one's own IRIS Explorer modules. Existing IRIS Explorer modules can be modified and renamed, or new ones can be created. Module Builder's graphical user interface allows one to build a basic module with no programming beyond that needed to write the computational functions in C, C++, or Fortran. The module-building process has three stages:

(1) defining the internal structure, or "the engine"
(2) defining the external structure, or the user interface, and
(3) building and installing the module in IRIS Explorer.

Project Definition

The 1996-97 computer visualization team focused on visualizing NASA datasets provided by the Earth Radiation Budget Experiment (ERBE). The goals of the ERBE are (1) to understand the radiation balance between the Sun, the Earth, the atmosphere, and space which moderates the weather and climate system and (2) to establish an accurate, long-term baseline dataset for studying climate changes. ERBE's data files were contained in the following thirteen parameters:

- box center latitude, degrees
- box center longitude, degrees
- short-wave reflected radiation, watts/meter^2
- long-wave emitted radiation, watts/meter^2
- net radiation, watts/meter^2
- albedo, percent
- clear-sky short-wave radiation, watts/meter^2
- clear-sky long-wave radiation, watts/meter^2
- clear-sky net radiation, watts/meter^2
- clear-sky albedo, percent
- long-wave cloud forcing, watts/meter^2

- short-wave cloud forcing, watts/meter^2
- net cloud forcing, watts/meter^2

Due to time constraints, the long-wave emitted radiation was studied in this project. Fortunately, the data had already been gridded which means to be distributed on a uniform grid. In order to visualize the data in color, the RGB color scheme was chosen to represent the longwave radiation data. This project consisted of three concentrations: (1) DataScribe which involved the data conversion process, (2) Module Builder which assisted with the building or use of modules, and (3) Map Editor which performed the rest of the needed operations such as the design and assembly phases. Each concentration will be described in the following sections.

DataScribe or dscribe

DataScribe is a component of the IRIS Explorer visualization software package and was very important because it converted the gridded NASA data from ASCII into a lattice format that IRIS Explorer could understand. Several preparations had to be made before actually building the conversion module. They included knowing the format of the input referred to as scalars and/or array of scalars and deciding the format of the output data which comes in the form of lattices. The lattice data type consists of two parts: the data values and the position of the data values in Cartesian space. There are three types of lattices which come in one to three dimensional lattices. They are the uniform lattices (the most commonly used), the perimenter lattices, and the curvilinear lattices. The two dimensional curvilinear lattice was chosen for the output lattice because it best represented the data used.

In the setup of DataScribe, one has two templates: the input and the output. They can be differentiated by viewing the directional arrow in the top left-hand corner of the template. One also has a detailed and abstract view of the templates.

To build the conversion module to click and drag the desired glyph whether it is a scalar or lattice from the data type palette to the DataScribe workspace. Each glyph has its own parameter which should be specified by the user, and a component box that may be used for further specifications. Once all the glyphs have been

selected, the input and output templates must be wired or connected together which forms a script or module which is loaded in the Map Editor's Librarian. This is turn can be contained in a map with other modules. Lastly, a check should be conducted for errors by parsing the script to make sure all perimeters are correct in the glyphs and the templates are wired correctly.

Module Builder or mbuilder

As mentioned earlier, the Module Builder is used to assemble modules. Although mbuilder wasn't used to the same extent as the other components, it had to be explored for this project. The modules provided by IRIS Explorer offer a range of functions, but sometimes it is necessary to construct new modules, providing a more specific function or a greater capacity than the existing ones. At first, it was thought that new modules would have to be constructed. But, it was determined that the existing ones could be used with a few modifications. The three main stages has to be followed in order to make modifications.

The definition of the internal structure involves creating a user function, defining the input and output ports, defining the function arguments, and defining the relationships between the inputs, outputs, and function arguments. The input port had to accept data in the form of the lattice data type. The module had to receive data on both its input port before it could fire, so each port had to be made a "Required" port. The output port produces a lattice output. The function arguments defined each function argument in the user function; each argument had to be connected to an input or output item. After all of the ports are defined, the proper connections are critical to the proper operation of the module.

The definition of the external structure involves designing a control panel and associating input parameters with control mechanims. A module has an interface that allows it to be controlled by the user. This interface is called the module control panel.

Finally, the construction and installation of the complete module finishes the process of module building. The module has to be turned into an executable program. The code is linked and compiled during the build process. When this stage is complete, the new module can be launched from IRIS Explorer's Module Librarian.

The Map Editor

IRIS Explorer's Map Editor is the environment in which maps are created and executed. The Module Librarian contains the available maps and modules. Maps can be used to perform a variety of tasks. The map was used to connect the needed modules in order to visualize the chosen NASA datasets.

In visualizing NASA datasets, the modules were used to generate a visual image from a specified dataset. The modules used for the visualization can be grouped according to their general function:

- "nasa_color" read in the data files,
- "Contour" developed the geometric representation in the form of a wire frame,
- "LatToGeom" developed the actual image,

and

- "Render" created the images.

In order to execute the "nasa_color" module, a data file had to be entered into the text box. As the module fires, its title bar turns yellow and stays yellow until the module has completed execution.

It was decided that the data collected for all of the year of 1988 and the November data from the years of 1984 to 1989 would be used. A computer program written in C was used to change the longitude and latitude measurements from degrees to radians. The program also coordinated the RGB color scheme of the radiation levels. The blue represented the highest readings; green represented the middle; the red represented the lowest; and the grey represented no readings. Once all preparations were completed, the individual datasets were ran separately through the map in order to form the images. There were two types of images produced: the flat representation and the global representation.

Conclusion

The ERBE provided many mediums in order to measure variations of regional radiative parameters. The study and visualization of other parameters such as shortwave radiation and cloud forcing are considerations for future work for the visualization team. Also, efficiency in the visualizations could

provide a means to predicting future climate changes. Contact with online users and other professionals could provide more insight into the world of visualization. It was observed that slight changes occurred in the longwave radiation each November over a four or five-year period. It can be loosely said that this is due to global warming of the earth. This observation needs further study.

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APPENDIX A

CONVERSION PROGRAM

SAMPLES OF ORIGINAL DATA AND CONVERTED DATA

```
/***CONVERSION  PROGRAM***/

#include <stdio.h>
#include <math.h>

void main()
  {

    float first, second, third;
    double oldlat, oldlong, newlat, newlong, shortwave, longwave;
    double netrad,  albedo, csshortwave, cslongwave, csnetrad,
    csalbedo, logfor;
    double shotfor, netfor;

    FILE  *in, *col, oldnasa, color;

   in  = fopen("data8411",  "r");
   col = fopen("ncolor8411",    "w");

    while(!feof(in))
       {fscanf(in, "%lf %lf %lf %lf %lf %lf %lf %lf %lf %lf %lf %lf %lf ",
       &oldlat, &oldlong, &shortwave, &longwave, &netrad, &albedo,
       &csshortwave, &cslongwave, &csnetrad, &csalbedo, &logfor,
       &shotfor, &netfor);

      oldlong = oldlong * 3.14 /180.0;
      oldlat  = oldlat  * 3.14 /180.0;
    if ( oldlong > 3.14) oldlong = oldlong - 6.28;
       oldlong = oldlong * cos (oldlat);


/*        oldlong = oldlong * 2.0  /180.0;
         oldlat  = oldlat  * 2.0 /180.0;

      if( oldlong > 2.00) oldlong = oldlong - 4.00;
        oldlong = oldlong * cos (oldlat);          */


    if(longwave < 155.0)
```

```
 { first  = 1.0;
  second = 0.0;
   third  = 0.0;
  fprintf(col,"%7.2f %7.2f %7.2f %7.2f  %7.2f \n",oldlat,
                oldlong, first, second, third);
}
else if (longwave < 160.0)
 { first  = 0.8;
  second = 0.0;
   third  = 0.0;
  fprintf(col,"%7.2f %7.2f %7.2f %7.2f  %7.2f \n",oldlat,
                oldlong, first, second, third);
}
 else if(longwave < 165.0)
 { first  = 0.6;
  second = 0.0;
   third  = 0.0;
  fprintf(col,"%7.2f %7.2f %7.2f %7.2f  %7.2f \n",oldlat,
                oldlong, first, second, third);
}
 else if(longwave < 175.0)
 { first  = 0.4;
  second = 0.0;
   third  = 0.0;
  fprintf(col,"%7.2f %7.2f %7.2f %7.2f  %7.2f \n",oldlat,
                oldlong,  first, second, third);
}
 else if(longwave < 185.0)
 { first  = 0.2;
  second = 0.0;
   third  = 0.0;
  fprintf(col,"%7.2f %7.2f %7.2f %7.2f  %7.2f \n",oldlat,
                oldlong, first, second, third);
}
 else if(longwave < 195.0)
 { first  = 0.0;
  second = 1.0;
   third  = 0.0;
  fprintf(col,"%7.2f %7.2f %7.2f %7.2f  %7.2f \n",oldlat,
                oldlong, first, second, third);
```

```
}
 else if(longwave < 205.0)
 { first  = 0.0;
  second = 0.8;
   third  = 0.0;
  fprintf(col,"%7.2f %7.2f %7.2f %7.2f  %7.2f \n",oldlat,
                oldlong, first, second, third);
}
 else if(longwave < 215.0)
 { first  = 0.0;
  second = 0.6;
   third  = 0.0;
  fprintf(col,"%7.2f %7.2f %7.2f %7.2f  %7.2f \n",oldlat,
                oldlong, first, second, third);
}
 else if(longwave < 225.0)
 { first  = 0.0;
  second = 0.4;
   third  = 0.0;
  fprintf(col,"%7.2f %7.2f %7.2f %7.2f  %7.2f \n",oldlat,
                oldlong, first, second, third);
}
 else if(longwave < 235.0)
 { first  = 0.0;
  second = 0.2;
   third  = 0.0;
  fprintf(col,"%7.2f %7.2f %7.2f %7.2f  %7.2f \n",oldlat,
                oldlong, first, second, third);
}
 else if(longwave < 245.0)
 { first  = 0.0;
  second = 0.0;
   third  = 1.0;
  fprintf(col,"%7.2f %7.2f %7.2f %7.2f  %7.2f \n",oldlat,
                oldlong, first, second, third);
}
 else if(longwave < 255.0)
 { first  = 0.0;
  second = 0.0;
   third  = 0.8;
```

```
 fprintf(col,"%7.2f %7.2f %7.2f %7.2f  %7.2f \n",oldlat,
              oldlong, first, second, third);
}
 else if(longwave < 265.0)
 { first  = 0.0;
  second = 0.0;
   third  = 0.6;
  fprintf(col,"%7.2f %7.2f %7.2f %7.2f  %7.2f \n",oldlat,
              oldlong, first, second, third);
}
 else if(longwave < 275.0)
 { first  = 0.0;
  second = 0.0;
   third  = 0.4;
  fprintf(col,"%7.2f %7.2f %7.2f %7.2f  %7.2f \n",oldlat,
              oldlong, first, second, third);
}
 else if(longwave < 285.0)
 { first  = 0.0;
  second = 0.0;
   third  = 0.2;
  fprintf(col,"%7.2f %7.2f %7.2f %7.2f  %7.2f \n",oldlat,
              oldlong, first, second, third);
}
 else if(longwave < 295.0)
 { first  = 0.0;
  second = 0.0;
   third  = 0.1;
  fprintf(col,"%7.2f %7.2f %7.2f %7.2f  %7.2f \n",oldlat,
              oldlong, first, second, third);
}
 else if(longwave = 999.99)
 { first  = 0.5;
  second = 0.5;
   third  = 0.5;
  fprintf(col,"%7.2f %7.2f %7.2f %7.2f  %7.2f \n",oldlat,
              oldlong, first, second, third);
}
 else
 { first  = 1.0;
```

```
                second = 1.0;
                third  = 1.0;
                fprintf(col,"%7.2f %7.2f %7.2f %7.2f  %7.2f \n",oldlat,
                        oldlong, first, second, third);
              }
    }
}
```

SAMPLE DATA BEFORE CONVERSION TO RADIANS

66.25 1.25 999.99 190.80 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99
66.25 3.75 999.99 189.00 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99
66.25 6.25 999.99 190.90 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99
66.25 8.75 999.99 195.50 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99
66.25 11.25 999.99 195.40 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99
66.25 13.75 999.99 189.40 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99
66.25 16.25 999.99 178.20 999.99 999.99 999.99 194.90 999.99 999.99 16.70 999.99 999.99
66.25 18.75 999.99 175.40 999.99 999.99 999.99 192.30 999.99 999.99 16.90 999.99 999.99
66.25 21.25 999.99 178.70 999.99 999.99 999.99 194.30 999.99 999.99 15.60 999.99 999.99
66.25 23.75 999.99 183.10 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99
66.25 26.25 999.99 180.60 999.99 999.99 999.99 193.40 999.99 999.99 12.80 999.99 999.99
66.25 28.75 999.99 178.30 999.99 999.99 999.99 190.80 999.99 999.99 12.50 999.99 999.99
66.25 31.25 999.99 178.00 999.99 999.99 999.99 189.40 999.99 999.99 11.40 999.99 999.99
66.25 33.75 999.99 180.00 999.99 999.99 999.99 190.10 999.99 999.99 10.10 999.99 999.99
66.25 36.25 999.99 181.10 999.99 999.99 999.99 190.80 999.99 999.99 9.70 999.99 999.99
66.25 38.75 999.99 183.90 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99 999.99
66.25 41.25 999.99 183.20 999.99 999.99 999.99 193.60 999.99 999.99 10.40 999.99 999.99
66.25 43.75 999.99 183.60 999.99 999.99 999.99 192.70 999.99 999.99 9.10 999.99 999.99
66.25 46.25 999.99 184.80 999.99 999.99 999.99 194.00 999.99 999.99 9.20 999.99 999.99
66.25 48.75 999.99 184.40 999.99 999.99 999.99 193.70 999.99 999.99 9.30 999.99 999.99
66.25 51.25 999.99 181.70 999.99 999.99 999.99 191.80 999.99 999.99 10.10 999.99 999.99
66.25 53.75 999.99 178.80 999.99 999.99 999.99 191.00 999.99 999.99 12.20 999.99 999.99
66.25 56.25 999.99 175.10 999.99 999.99 999.99 189.60 999.99 999.99 14.50 999.99 999.99
66.25 58.75 999.99 173.50 999.99 999.99 999.99 189.40 999.99 999.99 15.90 999.99 999.99
66.25 61.25 999.99 172.20 999.99 999.99 999.99 189.60 999.99 999.99 17.40 999.99 999.99
66.25 63.75 999.99 169.50 999.99 999.99 999.99 190.00 999.99 999.99 20.50 999.99 999.99
66.25 66.25 999.99 169.00 999.99 999.99 999.99 189.80 999.99 999.99 20.80 999.99 999.99
66.25 68.75 999.99 168.00 999.99 999.99 999.99 188.40 999.99 999.99 20.40 999.99 999.99
66.25 71.25 999.99 167.80 999.99 999.99 999.99 188.10 999.99 999.99 20.30 999.99 999.99
66.25 73.75 999.99 167.10 999.99 999.99 999.99 187.60 999.99 999.99 20.50 999.99 999.99
66.25 76.25 999.99 166.90 999.99 999.99 999.99 187.70 999.99 999.99 20.80 999.99 999.99
66.25 78.75 999.99 167.40 999.99 999.99 999.99 187.60 999.99 999.99 20.20 999.99 999.99
66.25 81.25 999.99 168.20 999.99 999.99 999.99 187.70 999.99 999.99 19.50 999.99 999.99
66.25 83.75 999.99 168.10 999.99 999.99 999.99 186.20 999.99 999.99 18.10 999.99 999.99
66.25 86.25 999.99 167.70 999.99 999.99 999.99 186.70 999.99 999.99 19.00 999.99 999.99
66.25 88.75 999.99 166.90 999.99 999.99 999.99 187.90 999.99 999.99 21.00 999.99 999.99
66.25 91.25 999.99 165.60 999.99 999.99 999.99 190.70 999.99 999.99 25.10 999.99 999.99
66.25 93.75 999.99 165.10 999.99 999.99 999.99 190.20 999.99 999.99 25.10 999.99 999.99
66.25 96.25 999.99 162.20 999.99 999.99 999.99 192.70 999.99 999.99 30.50 999.99 999.99
66.25 98.75 999.99 160.80 999.99 999.99 999.99 191.20 999.99 999.99 30.40 999.99 999.99
66.25 101.25 999.99 159.20 999.99 999.99 999.99 190.90 999.99 999.99 31.70 999.99 999.99
66.25 103.75 999.99 159.20 999.99 999.99 999.99 189.30 999.99 999.99 30.10 999.99 999.99
66.25 106.25 999.99 159.10 999.99 999.99 999.99 187.80 999.99 999.99 28.70 999.99 999.99
66.25 108.75 999.99 160.40 999.99 999.99 999.99 186.70 999.99 999.99 26.30 999.99 999.99
66.25 111.25 999.99 158.90 999.99 999.99 999.99 186.80 999.99 999.99 27.90 999.99 999.99
66.25 113.75 999.99 160.00 999.99 999.99 999.99 187.40 999.99 999.99 27.40 999.99 999.99
66.25 116.25 999.99 162.50 999.99 999.99 999.99 185.20 999.99 999.99 22.70 999.99 999.99
66.25 118.75 999.99 164.20 999.99 999.99 999.99 185.40 999.99 999.99 21.20 999.99 999.99
66.25 121.25 999.99 165.20 999.99 999.99 999.99 187.30 999.99 999.99 22.10 999.99 999.99
66.25 123.75 999.99 164.40 999.99 999.99 999.99 194.00 999.99 999.99 29.60 999.99 999.99
66.25 126.25 999.99 164.50 999.99 999.99 999.99 188.70 999.99 999.99 24.20 999.99 999.99

SAMPLE DATA AFTER CONVERSION TO RADIANS

144 54

1.16	0.01	0.00	1.00	0.00
1.16	0.03	0.00	1.00	0.00
1.16	0.04	0.00	1.00	0.00
1.16	0.06	0.00	0.80	0.00
1.16	0.08	0.00	0.80	0.00
1.16	0.10	0.00	1.00	0.00
1.16	0.11	0.20	0.00	0.00
1.16	0.13	0.20	0.00	0.00
1.16	0.15	0.20	0.00	0.00
1.16	0.17	0.20	0.00	0.00
1.16	0.18	0.20	0.00	0.00
1.16	0.20	0.20	0.00	0.00
1.16	0.22	0.20	0.00	0.00
1.16	0.24	0.20	0.00	0.00
1.16	0.26	0.20	0.00	0.00
1.16	0.27	0.20	0.00	0.00
1.16	0.29	0.20	0.00	0.00
1.16	0.31	0.20	0.00	0.00
1.16	0.33	0.20	0.00	0.00
1.16	0.34	0.20	0.00	0.00
1.16	0.36	0.20	0.00	0.00
1.16	0.38	0.20	0.00	0.00
1.16	0.40	0.20	0.00	0.00
1.16	0.41	0.40	0.00	0.00
1.16	0.43	0.40	0.00	0.00
1.16	0.45	0.40	0.00	0.00
1.16	0.47	0.40	0.00	0.00
1.16	0.48	0.40	0.00	0.00
1.16	0.50	0.40	0.00	0.00
1.16	0.52	0.40	0.00	0.00
1.16	0.54	0.40	0.00	0.00
1.16	0.55	0.40	0.00	0.00
1.16	0.57	0.40	0.00	0.00
1.16	0.59	0.40	0.00	0.00
1.16	0.61	0.40	0.00	0.00
1.16	0.62	0.40	0.00	0.00
1.16	0.64	0.40	0.00	0.00
1.16	0.66	0.40	0.00	0.00
1.16	0.68	0.60	0.00	0.00
1.16	0.69	0.60	0.00	0.00
1.16	0.71	0.80	0.00	0.00
1.16	0.73	0.80	0.00	0.00
1.16	0.75	0.80	0.00	0.00
1.16	0.77	0.60	0.00	0.00
1.16	0.78	0.80	0.00	0.00
1.16	0.80	0.60	0.00	0.00

Section V

- *Photos of Room 115 and 116 Lester Hall*


Room 116 Lester Hall
Room 116 Lester Hall


Room 115 Lester Hall
Room 116 Lester Hall